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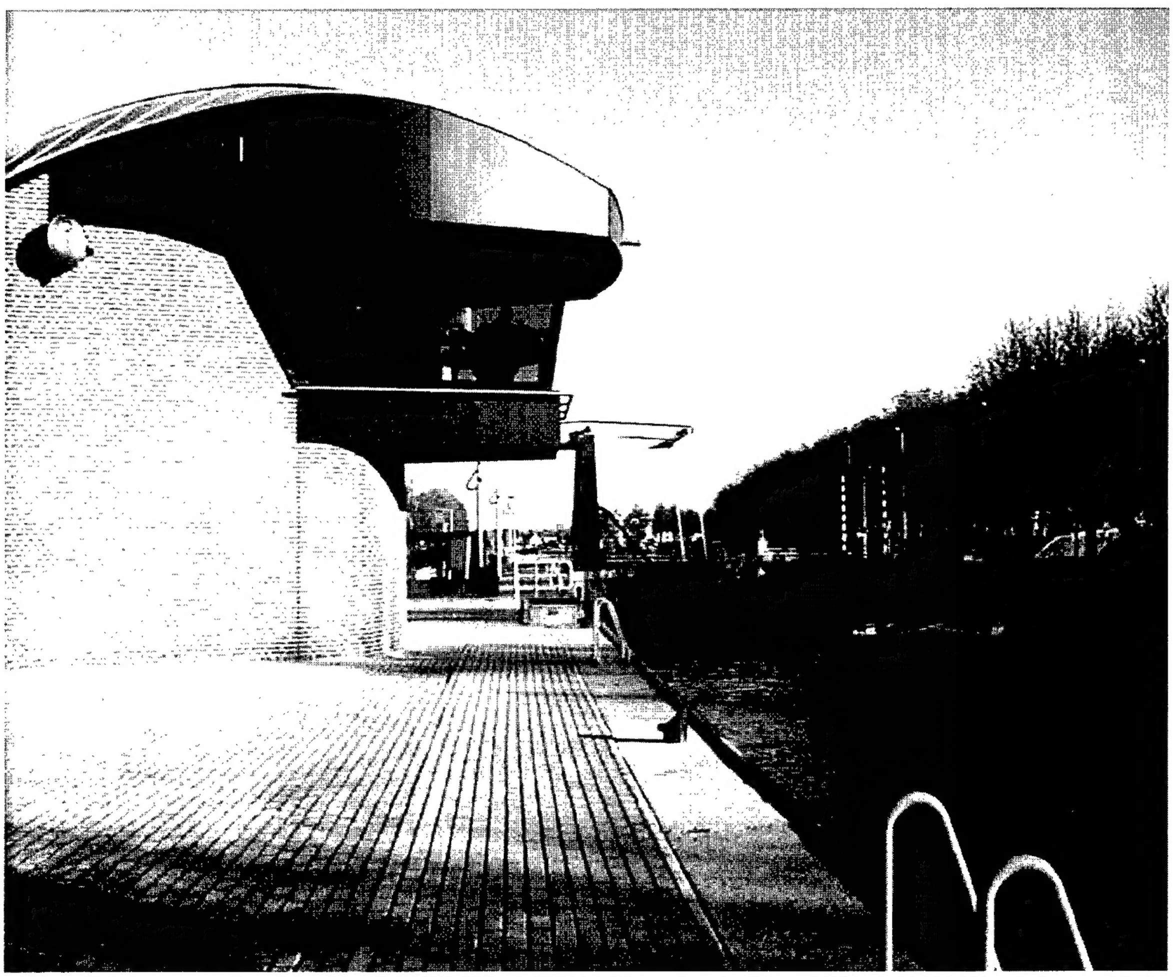
Innovations for Navigation Projects Research Program

Ergonomic Assessment of Navigation Lock Control Rooms and Consoles

John Pentikis

December 2000



Construction Engineering Research Laboratory

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Innovations for Navigation
Projects Research Program

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Ergonomic Assessment of Navigation Lock Control Rooms and Consoles

by John Pentikis

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Final report

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Preface

The work described in this report was authorized by Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the Innovations for Navigation Projects (INP) Research Program. The work was performed under Work Unit 33125, "Innovations for Lock Gate Operating Controls and Equipment."

Dr. Tony C. Liu was the INP Coordinator at the Directorate of Research and Development; Research Area Manager was Mr. Barry Holliday; and Program Monitor was Mr. Bruce Riley, HQUSACE. Mr. William H. McAnally of the U.S. Army Engineer Research and Development Center (ERDC) Coastal and Hydraulics Laboratory was the Lead Technical Director for Navigation Programs; Dr. Stanley C. Woodson, ERDC Geotechnical and Structures Laboratory, was the INP Program Manager.

Dr. L. David Stephenson, ERDC Construction Engineering Research Laboratory (CERL), was the Principal Investigator. The report was prepared by Mr. John Pentikis, U.S. Army Center for Health Promotion and Preventive Medicine, under the supervision of Dr. Stephenson, Materials and Structures Branch (CF-M); Mr. Martin J. Savoie, Chief, CF-M; and Mr. L. Michael Golish, Chief, Facilities Division, CERL. The associated Technical Director was Dr. Paul Howdyshell, and the Acting Director of CERL was Mr. William D. Goran.

At the time of publication of this report, Dr. James R. Houston was Director of ERDC, and COL James S. Weller, EN, was Commander.

1 Introduction

Background

The U.S. Army Corps of Engineers (USACE) is incorporating more automation into the operation of navigation locks as a way to improve safety, efficiency, and reliability. Automated navigation lock controls and equipment are in use on a limited basis by USACE, but implementation has been piecemeal with no standardization. The Construction Engineering Research Laboratory (CERL) is working with the many USACE districts to develop standardized guidance for the design of an automated system for operation and control of USACE lock gates.

Objectives

Between 23 September and 30 October 1998, the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) ergonomics team performed an ergonomic assessment of the lock control rooms and consoles at the Melvin Price Locks and Dam (Illinois), the Bonneville Lock and Dam (Oregon), the Kentucky Lock and Dam (Kentucky), and the Barkley Lock and Dam (Kentucky). Between 10 and 19 November 1999, the USACHPPM ergonomics team performed an ergonomic assessment of the lock control rooms and consoles at multiple sites in The Netherlands and Germany. The objectives of the assessments were to recommend ways to improve the ergonomic design of the lock control rooms and operator consoles and to help develop guidance for standardizing lock control rooms and consoles.

Approach

CERL contracted with the USACHPPM Ergonomics Program to assess USACE lock gate control rooms and operator consoles and to provide guidance and recommendations that address:

- The location and type of video monitors that will minimize operator eyestrain and neck strain.
- Control of glare inside the control room.
- The most effective layout of the control room.
- The most effective layout of the console control panel.
- The most effective layout of the computer displays.
- The adequacy of the furniture used.
- The most effective method of noise control inside the control room.
- The number of locks one operator can control before he or she starts to lose efficiency and effectiveness.
- Any other pertinent issues identified during the site visits.

The issues listed in the CERL Statement of Work (Appendix A) are addressed by the recommendations contained in Appendix B.

Major tasks performed by the USACHPPM ergonomics team to accomplish its mission were:

- *Visiting multiple lock control rooms specified by CERL.* On-site visits are essential to learn about the work. The goal of the on-site visits is to become fully acquainted with what the worker does (Burke 1992).
- *Interviewing site personnel.* Interviewing site personnel demonstrates that the opinions of the people who operate a workstation are valued. Specifically, the interviews allow the lock control operators to raise specific concerns about the job as well as provide suggestions on modifications that will improve the workstation (Burke 1992). Finally, if changes are made based on the recommendations of personnel, buy-in to those changes will be facilitated.
- *Distributing and analyzing the U.S. Air Force (USAF) Job Requirements and Physical Demands (JRPD) Survey.* The survey provides a means for personnel to identify specific work processes, activities, and tasks that they believe are related to their reported musculoskeletal discomfort and/or work-related musculoskeletal disorders. Additionally, the results of the survey, which are based on ergonomic, psychosocial, and individual factors, will help the ergonomics team develop recommendations to improve the workstation (USACHPPM 1998).
- *Observing the layout of the control rooms.* The ergonomics team observed the navigation lock control room layout and measured all static elements in the room, including work heights, reach distances, and clearances under desks.

These measurements determine which components of the workstation need to be redesigned. Appendix C contains a list of the ergonomic design principles used.

- *Reviewing Draft Engineer Manual (EM) 1110-2-2610.* The ergonomics team reviewed Draft EM 1110-2-2610, *Gate Operating Equipment for Navigation Locks and Spillways,* to ensure ergonomic considerations were incorporated and to provide recommendations when appropriate. Appendix D contains all comments pertaining to Draft EM 1110-2-2610.

Mode of Technology Transfer

Recommendations will be incorporated in Engineer Manual 1110-2-2610.

Units of Weight and Measure

U.S. standard units of measure are used throughout this report. A table of conversion factors for Standard International (SI) units is provided below.

SI conversion factors		
1 in.	=	2.54 cm
1 ft	=	0.305 m
1 sq ft	=	0.093 m^2

2 Results

Control Room Visits

The USACHPPM ergonomics team visited four USACE navigation lock control rooms where automated control systems had been implemented. The site locations were the Melvin Price Locks and Dam in Illinois; the Bonneville Lock and Dam in Oregon; the Kentucky Lock and Dam and the Barkley Lock and Dam, both in Kentucky. The ergonomics team also visited eight lock control rooms in The Netherlands and in Germany to assess European designs. Appendix E contains the results of the European lock control room visits.

The team's observations of the navigation lock control rooms are as follows:

- Control room operators spent a lot of time talking on the telephone.
- Control room operators made many adjustments trying to combat the effects of glare in the control room.
- Entering data into the Operations and Management of Navigation Installations (OMNI) computer program for vessel logging and tracking purposes might require up to 30 percent of the work shift.
- Workstations were designed for sitting, yet many operators stood to perform most of their job tasks.
- Viewing monitors is essential to doing a safe job.

Interview of Site Personnel

Findings from the navigation lock operator interviews are separated into four categories: control room equipment, control room design features, psychosocial issues, and other.

Control Room Equipment

- The control panel was too far from the window. Operators need to view the lock from the window.

- The location of the closed-circuit television (CCTV) monitors forces operators to hold their necks in a non-neutral posture (neck extension). Neck discomfort can result.
- Three workstations in the control room were too many for the size of the room. The operators would like to see at least one workstation removed. Figures 1 through 3 show multiple workstations in a local lock control room.
- The chairs in use were not fully adjustable and not very comfortable. Figures 4 and 5 show samples of chairs used in the lock control rooms.
- The number of CCTV monitors did not match the number of CCTV sets used.
- The CCTV monitors needed to be updated to better display the image from the newer television cameras.
- The controls for the CCTV cameras were not conveniently located.

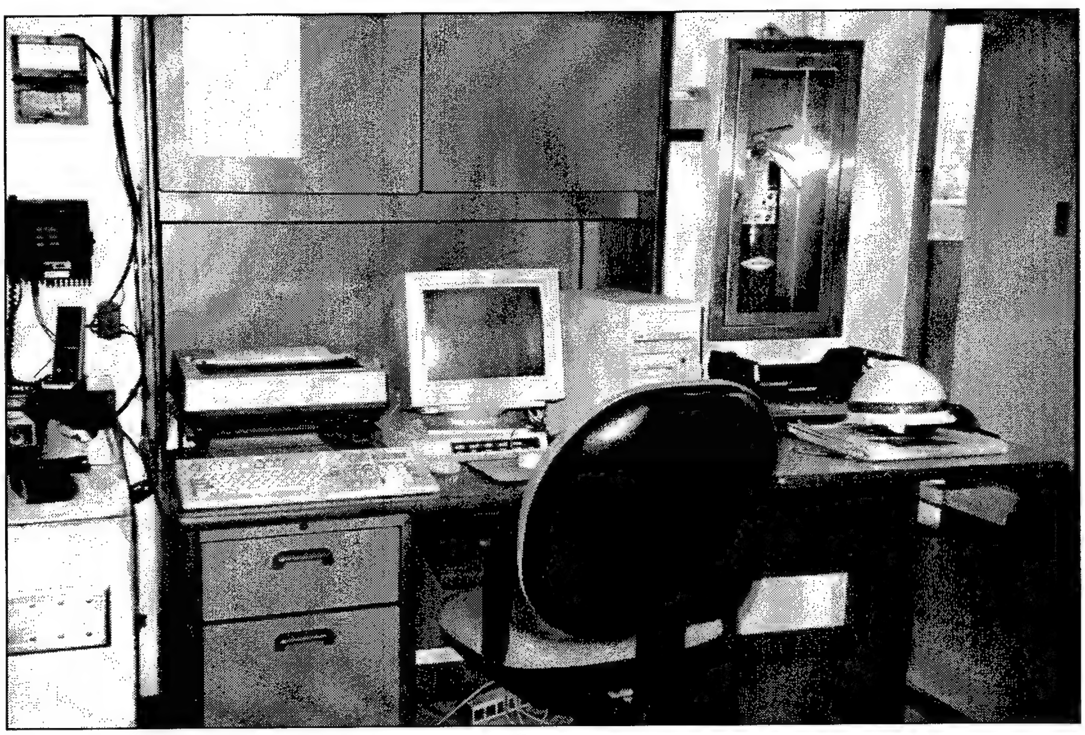

Figure 1. Workstation 1 in a control room.

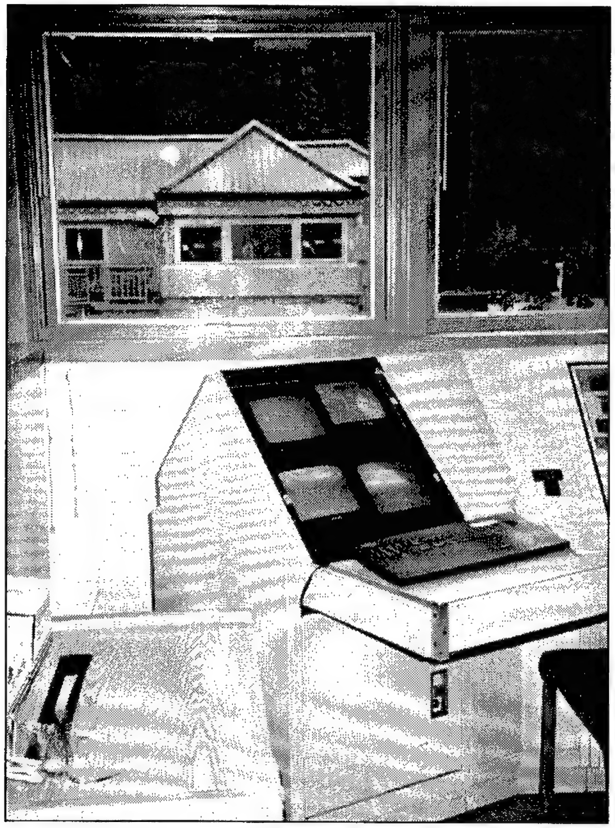

Figure 2. Workstation 2 in a control room.

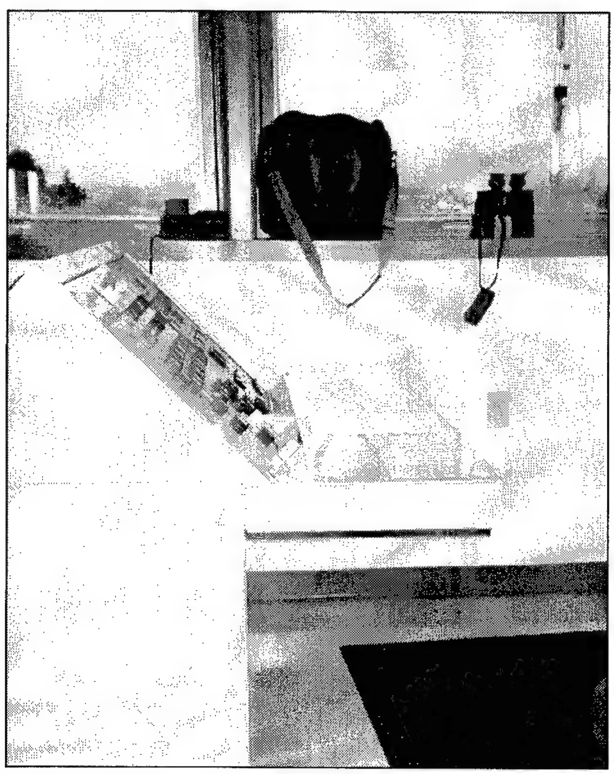

Figure 3. Workstation 3 in a control room.

Figure 4. Sample chair used in a control room.

Figure 5. Sample chair used in a control room.

Control Room Design Features

- The control room was too far away from the locks, thereby hindering visibility of the locks.
- The control room was too hot in the summer and, conceivably, could be too hot on sunny days even in winter.
- The control room was too cold in the winter. Aside from the discomfort to the operators, the cold temperature caused the windows to frost/fog. When this occurred, the operator could not see out the window.
- Too much glare in the control room made it difficult for operators to look at the CCTV monitors and the computer monitor. Also, the glare "bleached out" the light switches (used as a coding system to distinguish if a switch is active or not) on the control panel. Figure 6 illustrates the effects of glare in the lock control room.
- The floor surface was too hard. Operators who stood during their shift found that their legs were tired and fatigued by the end of the work shift.
- Control of indoor light levels was difficult.

Figure 6. Effects of glare in the control room.

Psychosocial Issues

- Visitors became annoyed if operators did not talk to them. Note: Operators try to accommodate visitors, but there are times when they are busy and cannot talk.
- The security response time was poor. Operators indicated that it took 30 minutes for security personnel to respond to their calls.
- Security checks did not occur as frequently as they used to.
- The lock area was not very secure, and a lot of people seemed to be just "hanging around" in this area.
- Recreational craft operators did not know proper locking procedures or they ignored safety procedures.
- Operators spent too much time responding to telephone calls.
- The intercom system needed to be improved. Two-way communication was not possible, and people did not always understand the lock operator due to echoing.
- Shift workers rotated backward in time rather than the preferred forward in time.
- The break room needed additional equipment including a full kitchen and an intercom.
- The range of the portable intercom needed to be improved to allow operators more freedom when working outside of the control room.

Other

- Extra CCTV cameras were needed to help monitor the locks.
- Spider webs on the closed-circuit video cameras reflected light that impaired the monitor display.
- Bright light caused shadows and diminished the capabilities of the closed-circuit video cameras; it "bleached out" the image that was being viewed.
- Color cameras are not as light-sensitive for night use as black and white cameras.
- Additional lighting was needed outside to help closed-circuit cameras capture more detail.
- Operators did not approve of the lock control room phone number being listed in the telephone book. They felt the easy access to their number caused too many people to call looking for information that could have been obtained elsewhere.

Job Requirements and Physical Demands Survey

The USACHPPM ergonomics team left JRPD survey forms at the Melvin Price Locks, Bonneville Lock, and the Barkley Lock with instructions to forward the completed forms to the USACHPPM Ergonomics Program. Appendix F contains a sample JRPD survey form. A total of 27 forms were received — 7 from the Melvin Price Locks, 9 from the Bonneville Lock, and 11 from the Barkley Lock. Appendix G contains summaries for each lock location, an overall summary for all of the locations, and guidance on how to interpret the results.

Findings from the JRPD survey are as follows:

- The lock operators at the Barkley Lock had a high degree of self-reporting of discomfort and a high degree of risk for an injury to the legs and head/eye.
- The lock operators at the Melvin Price Locks had a high degree of self-reporting of discomfort and a high degree of risk for an injury to the head/eye.
- The lock operators at all locations indicated that their job stress factors were of minimal concern.
- The lock operators at all locations indicated that their average physical effort was minimal, ranking between very light and light.
- The workforce is getting older, with 11 of the 27 lock operators being more than 50 years old.
- Some 55 percent of the Barkley Lock operators, 43 percent of the Melvin Price Locks operators, and 22 percent of the Bonneville Lock operators indicated that they experienced work-related pain or discomfort that did not improve when they were away from work overnight or over the weekend.
- Some 29 percent of the Melvin Price Locks operators, 27 percent of the Barkley Lock operators, and 22 percent of the Bonneville Lock operators indicated that their work-related pain or discomfort made normal activities (job, hobby, leisure, etc.) difficult.
- A full 80 percent of the lock operators (four out of five people) diagnosed with a work-related musculoskeletal disorder injury were from the Melvin Price Locks.
- Four of the 11 Barkley Lock operators reported that taking the haulage unit control to the lock wall was the task requiring work in the most uncomfortable position. Three of the operators cited moving materials from the vessel to the lock as the task requiring work in the most uncomfortable position.
- Three of the seven Melvin Price Locks operators reported that viewing the monitors while operating the miter gates was the task requiring work in the

most uncomfortable position. They also cited this task as the one requiring the most effort to perform.

- The Bonneville Lock operators did not have a consensus regarding tasks requiring work in the most uncomfortable position. Out of nine operators, one cited lying down or kneeling, one cited climbing steps, and one cited walking during inclement weather as uncomfortable.
- Three of the 11 Barkley Lock operators reported that pulling cuts out of the chamber was the task that required the most effort during tow haulage operations. Two operators cited removing or installing equipment and lifting heavy lock lines as the tasks that required the most effort.
- Two of the nine Bonneville Lock operators indicated that working in deep snow/ice was the task requiring the most effort.
- Five of the 11 Barkley Lock operators cited the haulage unit as the tool or piece of equipment that was notoriously hard to work with; they mentioned no other tool or piece of equipment.
- One of the nine Bonneville Lock operators cited the swing bridge as the tool or piece of equipment that was notoriously hard to work with; the operators did not mention any other tool or piece of equipment.
- Only one suggestion (cited more than once) came from the two localized lock locations. Three Barkley Lock operators suggested that there be one centralized control stand. Appendix H contains all of the lock operators' suggestions.

Control Room Layout Observations

Observations from the navigation lock control rooms are as follows:

- Multiple workstations were in use.
- Navigation lock control room workstations were not well-organized due to modification of existing equipment or the addition of new equipment.
- The addition of new equipment made some of the navigation lock control rooms cramped (see Figure 7).
- Inadequate equipment (chair and desk) supported computer workstations (see Figure 8).
- Much glare was present in the navigation lock control rooms.
- The arrangement of CCTV monitors was poor.
- Spider webs on the closed-circuit cameras impaired the visibility of the navigation lock operators.
- The operator console and lock gate control rooms needed to be relocated.

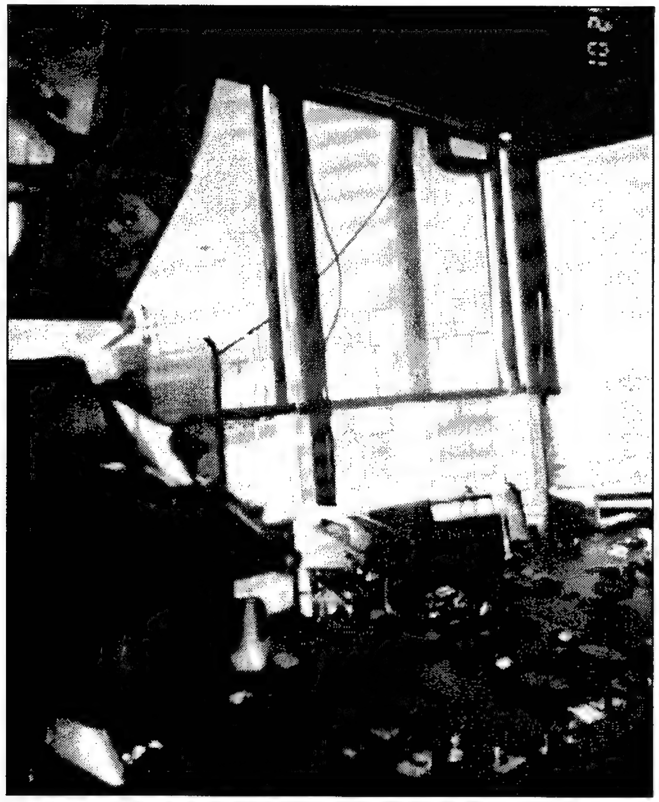

Figure 7. Cramped control room.

Figure 8. Sample computer workstation.

3 Findings, Discussion, and Recommendations

During the site visits to the four navigation lock control rooms, the USACHPPM ergonomics team discussed many issues with personnel and observed many operations. The findings were separated into four categories: building, workstation, psychosocial factors, and other observations. The following sections will discuss each category individually and provide a basis for all recommendations.

Building

The majority of the findings relative to the navigation lock control room were similar regardless of whether the control room was centrally located or was an individual control room. Figure 9 shows a centralized lock control room, while Figure 10 shows a local lock control room. Appendix I contains recommendations specific to improvements in the building and furnishing of a lock control room.

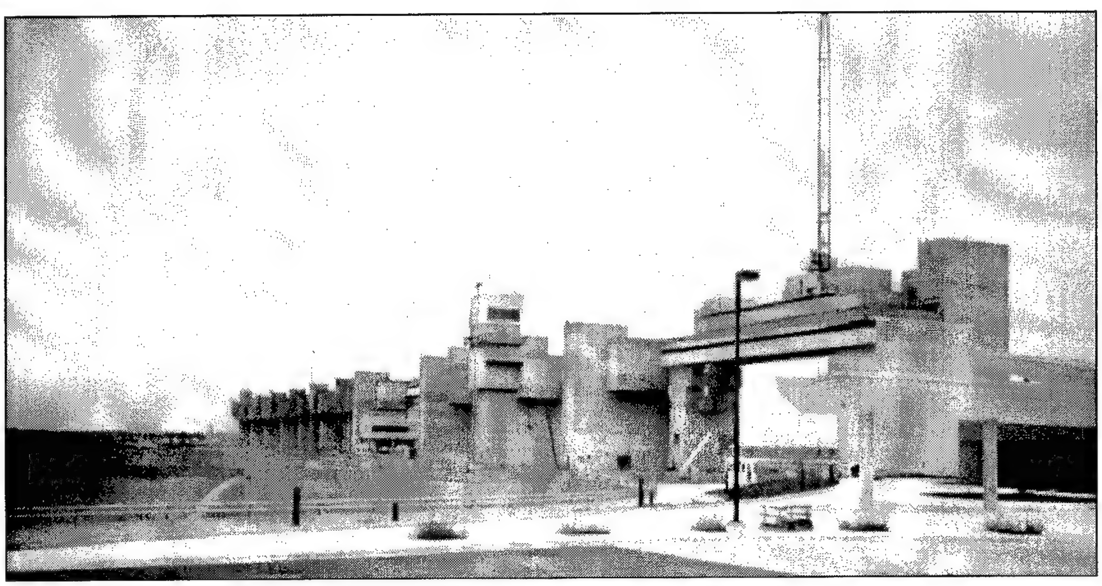

Figure 9. Central lock control room (Melvin Price Locks and Dam).

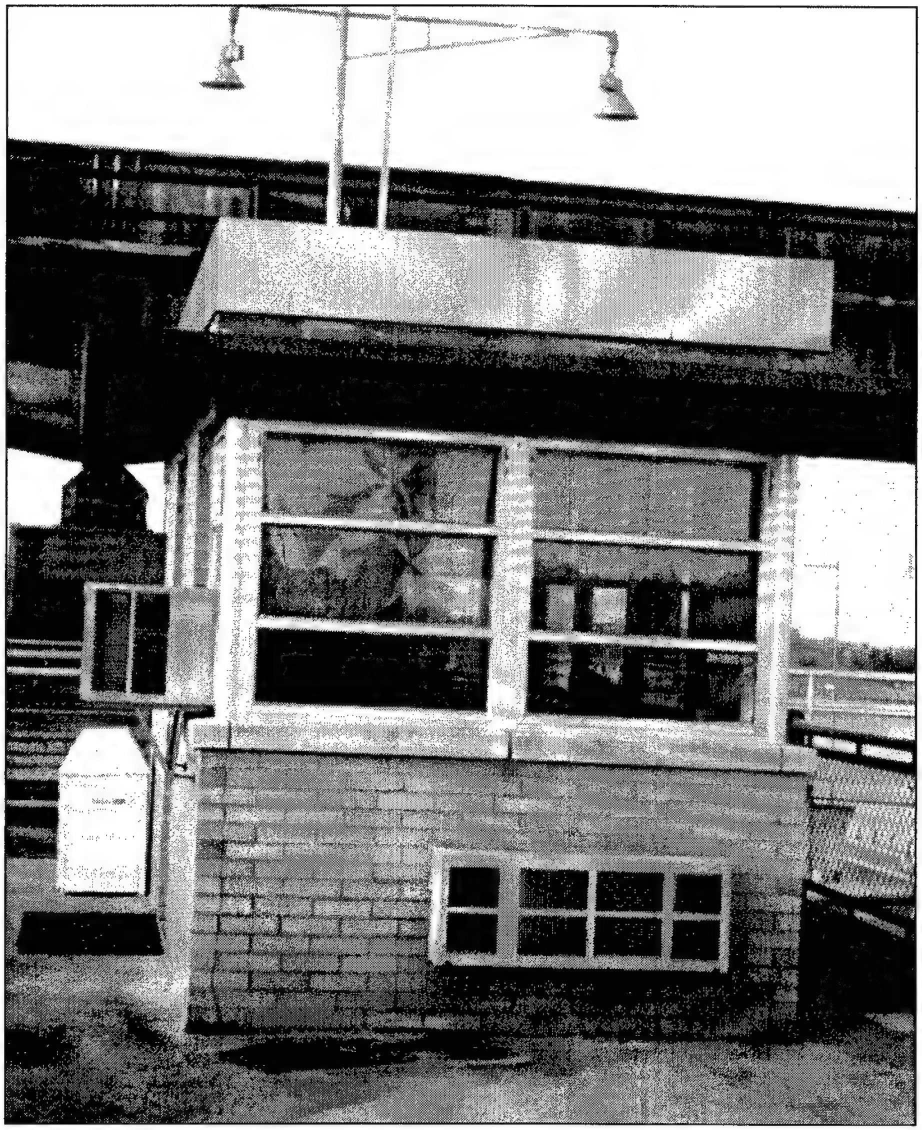

Figure 10. Local lock control room (Barkley Lock and Dam).

Centrally located control rooms were typically in a tower or building that overlooked the river and lock chambers. The operator was located farther away from the lock chambers than were individual control room operators. Therefore, the operator in a centrally located control room depended more on the CCTV system. In individual control rooms, the operators were much closer to the lock and were more apt to use their eyesight as the primary information collection tool with the CCTV monitors as a backup.

Finding 1

The most commonly cited problem in the control rooms was uncomfortable environmental conditions. The rooms tended to be hot in the summer and cold in the winter.

Discussion. Windows occupied much of the wall space in almost all of the control rooms. Additionally, the walls and roof were often exposed to outside elements. These two conditions placed a lot of stress on the heating and cooling units of the control rooms.

Employees hardly notice the internal climate of a room as long as it is "normal," but the more it deviates from a comfortable standard, the more it attracts attention. The sensation of discomfort brings about functional changes that may affect the entire body. Overheating leads to weariness and sleepiness, reduced physical performance, and increased liability to errors. Conversely, overcooling induces restlessness, which in turn reduces alertness and concentration, particularly on mental tasks. Thus the maintenance of a comfortable climate indoors is essential for well-being and performance at maximum efficiency (Kroemer and Grandjean 1997).

Normally, employees who are not comfortable in the workplace do not have access to the thermostat. Unfortunately, the lock control room employees were subjected to environmental discomforts even though they could regulate the thermostat inside the control room. Therefore, improvements in the heating and cooling systems are needed.

Recommendations.

- Since people find a range of temperatures comfortable, provide multiple ways for employees to alter the environmental conditions in the control room.
- Ensure that the heating and cooling units installed in the control rooms are adequate. (This adequacy should be based on the actual environmental conditions of the control room rather than on cubic footage of the room.)
- Install double or triple pane windows that can open and close.
- Provide coatings on the windows, shades, and/or blinds to control the amount of sunlight entering the room.
- Ensure that the control rooms are well insulated.
- Provide heaters or fans as short-term solutions to help regulate temperatures until more permanent solutions are instituted.

Finding 2

The control room filled with glare whenever the sun was shining.

Discussion. Glare is produced by brightness within the field of vision that is sufficiently greater than the luminance to which the eyes are adapted so as to cause annoyance, discomfort, or loss in visual performance and visibility (Sanders and McCormick 1993). Although all the control rooms visited had blinds or shades, control room employees indicated that more needed to be done to combat the amount of glare to which they were exposed. Figure 11 shows shades used at the Melvin Price Locks.

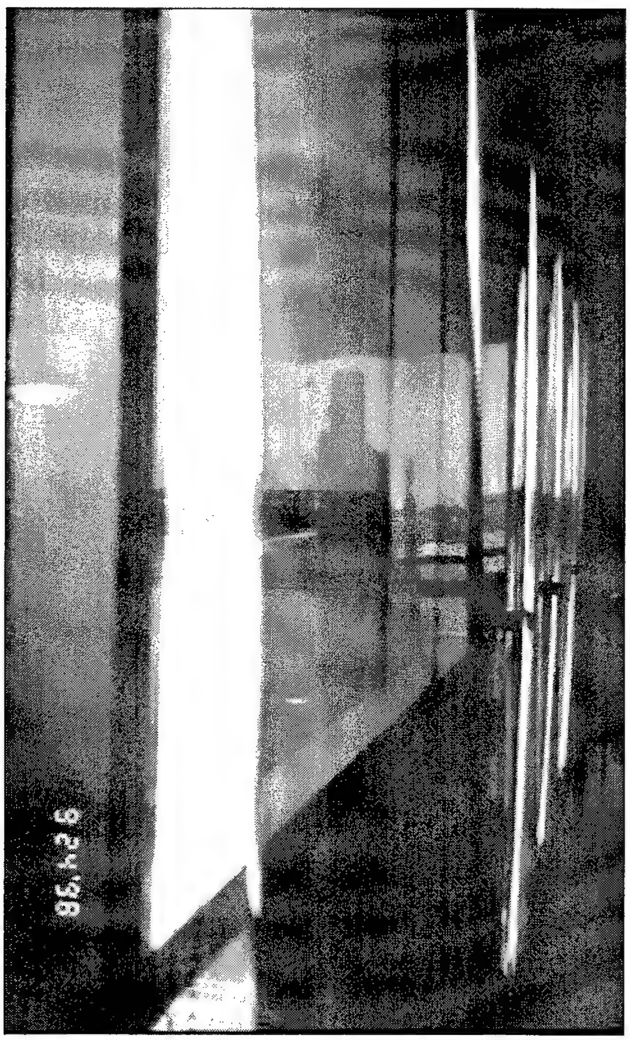

Figure 11. Shades used at Melvin Price Locks Control Room.

Recommendations. Glare is best combated by eliminating it before it reaches the user.

- Install windows that have a tilt of 20 degrees (DOT 1972).
- Install solar insulating film on all windows.
- Install electronically tinted glass (if feasible).
- Provide blinds and shades for all windows.
- Provide antiglare screens to all CCTV and computer monitors as short-term solutions until more permanent solutions are instituted.

Finding 3

The floor surface in the control room was too hard.

Discussion. Many of the control room operators spent the majority of their workday standing. Standing on hard floor surfaces causes fatigue in the feet, legs, and back (Konz 1995).

Recommendation. Provide appropriate antifatigue matting. Matting should be at least ½-in. thick and provide cushioning to the feet.

Finding 4

One of the local control room configurations (Barkley) was too far from the lock.

Discussion. The goal of the local control room configuration is for the operator to sit at the control console and see the vessel in the lock. However, due to the location of the local control room, the operator had to stand and lean over the control console to see the vessel in the lock and then sit down to operate the console. This posturing defeats the purpose of the local control room and also may lead to an accident due to the operator inadvertently activating a switch when leaning over the control panel.

Recommendation. When designing, updating, or adding control room equipment, ensure the lock operator's line of sight is not impeded.

Finding 5

Control of the indoor light levels was difficult.

Discussion. For most jobs, vision is the main sensory channel for receiving information. Illumination, therefore, is a critical element in the design of any workplace. Without adequate lighting, important task elements may be incorrectly seen or not seen at all (Eastman Kodak Co. 1983). In most of the control rooms, the lighting was fluorescent rather than incandescent. The operators had no mechanism, therefore, to dim the lights or adjust it to a comfortable level. Their only choice was to turn a particular light fixture on or off.

Recommendations.

- Only provide incandescent lighting to the control room.
- Install dimmer switches to all lights in the control room.

Finding 6

Amenities in the centralized control room lounge area were not sufficient to support the control room operators.

Discussion. The amenities in the centralized control room did not match the amenities provided in other buildings implying that the employees of the control room are not as deserving as other employees. This feeling of inadequacy may not be warranted, but it did exist. Additionally, Maslow's stairs, a hierarchy of individual wants, indicates physical comfort on the job is one of the most basic individual wants of an employee (Konz 1995). Not providing these wants may result in employee discontent.

Recommendation. Ensure that centrally located control rooms are equipped with the same amenities as other break rooms in the lock and dam compound. As a general rule, if a lock operator has to leave the centrally located control room to obtain an amenity, then the control room amenities are inadequate.

Workstation

The equipment used to operate the navigation locks in the control rooms is current and is continually updated. Just as important as the navigation lock control room equipment are the control room furniture and the room layout. Both were inadequate. To further complicate matters, multiple users work in the control rooms meaning many individuals need to be accommodated.

Finding 1

Workstations are designed for seated operation, and the workstations are not fully adjustable.

Discussion. Control room operators do not necessarily sit down when operating the console. Also, body sizes and shapes vary widely among the console operators. Furthermore, the only piece of adjustable furniture in the room is the chair. Given these factors, it is very unlikely that any of the control room employees work in a comfortable or efficient manner. To ensure more comfort and better efficiency at a workstation where multiple users operate the equipment, the general principle of designing for the range should be employed.

Certain pieces of equipment can be designed so that they can be adjusted to fit the individuals who use them. A well-designed, fully adjustable chair will promote appropriate body postures, maintain adequate circulation in the body, and reduce the amount of strain on the spine, as well as allow freedom of movement. An adjustable desk height will provide even more freedom for the operator to adapt the work environment to meet his or her individual needs based on size, personal preferences, etc.

Recommendations.

- Decide whether the lock control room is to be operated by a standing operator, a seated operator, or an operator who both sits and stands.
- Provide chairs and desks that can be easily adjusted to meet the needs of the 5th percentile female to the 95th percentile male whether operators are standing or sitting.
- Ensure adequate leg clearance under the control panel.
- Ensure the depth of the control panel allows the 5th percentile female to easily reach all controls.

Finding 2

The control panel was too far away from the window. Figure 12 shows the monitor location at the Melvin Price Locks.

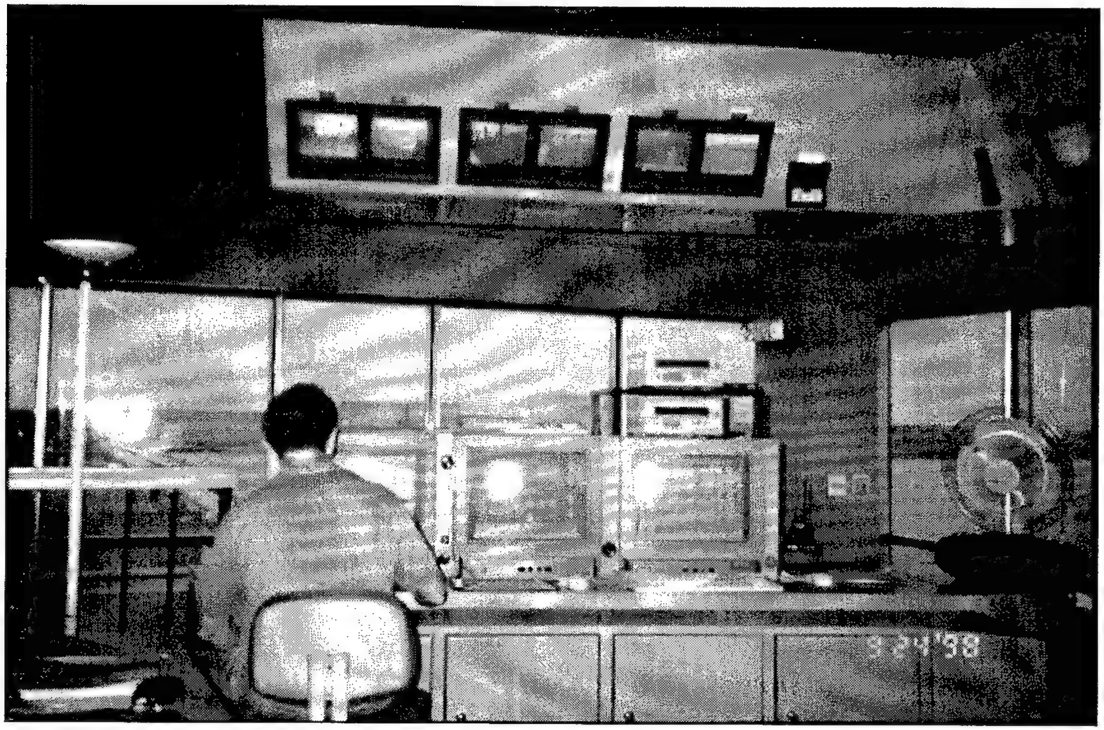

Figure 12. Monitor location at Melvin Price Locks Control Room.

Discussion. The goal of the local control room configuration is for the operator to sit at the control console and see the vessel in the lock. However, due to the location of the control panel in relation to the window, the operator had to stand and lean over the control console or walk in front of the control panel to see the vessel in the lock and then sit down to operate the console. This posturing defeats the purpose of the local control room and also may lead to an accident due to the operator inadvertently activating a switch when leaning over the control panel.

Recommendation. When designing, updating, or adding control room equipment, ensure the lock operator's line of sight is not impeded.

Finding 3

The CCTV monitors were not conveniently located.

Discussion. The most common complaint regarding the equipment used by the lock control room operators was the location of the CCTV monitors. Whether the monitors were attached to the ceiling, recessed into the control room console, or hung on articulating arms, at least one employee from all the lock control rooms visited complained of the monitor location. Research has shown that people prefer to look downward to close visual targets by inclining the head forward and

rotating the eyeballs downward (Kroemer, Kroemer, and Kroemer-Elbert 1994). Researchers also agree that the "normal" line of sight is 10 to 15 degrees below the horizontal plane. This position can also be thought of as the resting condition of the eye. Therefore, a display or any other visual target should be placed within a viewing angle of 5 degrees above and 30 degrees below the horizontal plane (Grandjean 1987).

In theory, the operators who could position the monitors with an articulating arm should have had no complaints about the monitor position since they were free to move the monitor to any position they desired. However, observers noted that the monitors were not repositioned by the operators. Figure 13 shows monitors on adjustable stands.

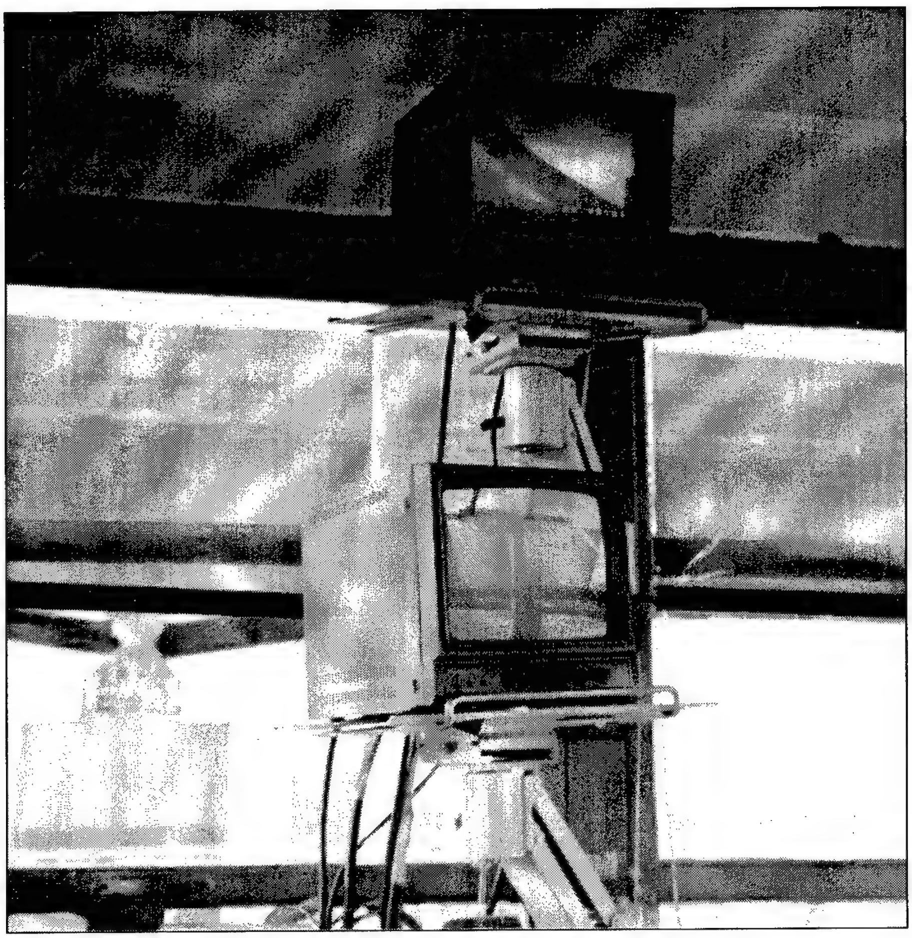

Figure 13. Monitors on adjustable stands.

Recommendations.

- Provide adjustable monitors that can be positioned within a viewing angle of 5 degrees above and 30 degrees below the horizontal plane.
- Ensure monitor placement does not interfere with the line of sight of the lock operators.
- Train operators in the benefits of adjusting the monitor height so they can work in a neutral and comfortable posture.

Finding 4

Multiple workstations were used in the lock control rooms. Additional equipment was housed in the control room, and workstations were in disorder.

Discussion. The lock control room operators had to use at least three distinct workstations: one for the console to operate the lock, one for the computer that housed the OMNI software, and one for the communication equipment (intercom and telephone). Depending on the specific requirements of the lock, one or more workstations might also be present. Space utilization has yet to become a problem in the central control rooms because there is room to house the new or updated equipment. In the older local control rooms, however, space requirements have become an issue.

Two of the local control rooms visited measured 7.5 ft by 15 ft. When the building was designed, this space may have been more than adequate. Today, however, the control rooms are cramped due to the addition of a personal computer to operate the OMNI software, the addition of CCTV monitors, temperature/wind monitors, more dependence on the telephone, and, in some cases, a backup system to control the lock. All this equipment in a confined area forced the lock control operator to adjust his or her posture when operating the equipment.

Also, the addition or updating of equipment caused the workstations to appear to be in disorder. Often when new equipment is purchased, not enough emphasis is placed on the best way to integrate the new equipment into the existing workstation. Thus, it is possible that a new piece of equipment, purchased to make an employee's job easier, may in fact make his or her job more difficult.

Recommendations.

- Ensure space is sufficient in the lock control room for new furniture or equipment.
- Ensure all new equipment can be integrated into the existing design of the lock control room.
- Ensure appropriate workstation furniture is provided when a new workstation is introduced into the control room.

Finding 5

CCTV monitors need to be updated.

Discussion. Many of the lock operators mentioned that the CCTV monitors were old. One operator reported that the monitor used might be more than 20 years old. The monitors provide essential visual feedback to the lock operators. Operators use the monitors to ensure the safety of the lock and the safety of the people who use the lock and their vessels. Although the equipment is still functional, it is not technologically current. The contrast and sharpness of the picture could be improved. The lock operators could perform their jobs more safely and efficiently if the equipment they use could be updated.

Recommendation. Provide CCTV monitors that are technologically current so that a higher quality of picture is displayed.

Finding 6

The number of CCTV cameras did not match the number of CCTV monitors.

Discussion. Lock operators indicated that keeping track of which camera angles are being displayed can be confusing when there are fewer monitors than cameras available. The lock operators also felt this situation became even worse when conditions were stressful. They stated their jobs would be easier if every camera had a dedicated monitor.

Recommendations.

- Provide a CCTV monitor for every CCTV camera whenever it is possible and practical to do so.

- Investigate the use of using larger video monitors in conjunction with a quad unit. With a quad unit, four camera views can be displayed on one monitor.

Finding 7

More cameras are needed to monitor the locks.

Discussion. As already mentioned, the lock operators depended heavily on the CCTV system to perform their jobs. Many operators expressed an interest in obtaining more camera views to enhance job performance. More camera views would provide more than one option for viewing the lock at times when extreme glare causes a camera display to be "bleached out." Lock operators also mentioned that they could do without the added cameras if new cameras that provided enough contrast during sunny conditions were purchased.

Recommendation. Provide more CCTV cameras according to lock operator specifications.

Finding 8

The computer workstation setup was inadequate.

Discussion. The control room was observed to be in disarray due to the addition of new equipment such as a personal computer. The computer was added to the workstation so the lock operator could keep vessel tracking records using the OMNI software package. The chairs used were adequate, but the desks were poor since they did not offer any adjustable features. Since lock operators spend 1 to 2 hr at their workstations at one time, their computer workstation setups must be fully and easily adjustable. This finding is significant since inadequacy of design or dimension will, in the long run, generate static efforts associated with muscle fatigue, stiffness, and pain in the neck-shoulders-arm-hand region (Grandjean 1987).

Recommendation. Provide the lock control room with a computer workstation that features an easily and fully adjustable chair, a desk that is adjustable or has an articulating keyboard arm, and a work surface area large enough to accommodate a keyboard and mouse.

Psychosocial Factors

Stress does not always lead to ill effects or decreased job performance. In fact, human performance is low at low levels of stress. Job performance will be at an optimum with some degree of stress. However, too much stress associated with the job will result in a drop-off in efficiency, which is known as the overload condition. There is simply too much for the person to do or attend to (Pulat 1992). The stress state is usually accompanied by a characteristic mood change and possibly by a more intense and focused emotional experience when the person feels tense or anxious, worn-out, or fatigued. Such moods and emotions are unpleasant, and on most occasions serve to define the stress state for the individual (Wilson and Corlett 1990). Therefore, the goal of the site surveys is not to eliminate all forms of stress but rather to identify those stressful aspects of the job that may lead to an overload situation.

Finding 1

Security of the locks needs to be improved.

Discussion. Lock operators mentioned that security of the locks can be improved. Issues cited were the response time of security personnel and the frequency of security checks. Responses to a call can take up to 30 minutes. The lock operators said that the security checks do not happen as frequently as they once did. This leads some lock operators to feel vulnerable when at work.

Recommendation. Review the current security procedures in relation to the needs of the lock operators, especially those operators who work when few people are around. Determine if additional security is needed or if the level of security being provided needs to be improved.

Finding 2

Visitors were often unpredictable, thereby increasing the operators' stress levels.

Discussion. During interviews with lock operators, they were asked how they felt about the lock being open to visitors. The lock operators mentioned the following distractions: some visitors armed themselves with the intent of shooting fish in the lock; prostitutes called the lock operators asking for permission to cross the river so they could meet their "dates" on the other side of the river; people loitered about the dam without any purpose or reason for being there; and

visitors got upset if the lock operators did not talk to them. The lock operators mentioned that they would be happy to answer questions when they were not busy, but when a vessel was in the lock, they did not have time to answer questions. Although these observations were the exceptions rather than the rule, these situations do add stress to the lock operator's job.

Recommendation. Review the current security procedures in relation to the needs of the lock operators, especially those operators who work when few people are around. Determine if additional security is needed or if the level of security being provided needs to be improved.

Finding 3

Recreational craft operators did not follow lock operator instructions.

Discussion. Although the number of recreational craft was significantly smaller than the number of barges, lock operators found locking the recreational craft to be more stressful. The smaller craft are more susceptible to the turbulent water flow when the chamber is emptied or filled, and recreational craft operators are less likely to know or follow proper locking techniques. The recreational craft operators did not always follow the instructions of the lock operators, thereby adding to their stress levels.

Recommendations.

- Require recreational craft operators to be trained in proper locking techniques.
- Provide a mechanism for recreational craft operators to be fined or punished for not obeying lock operator instructions.

Finding 4

The intercom system was not adequate.

Discussion. Lock operators mentioned two problems concerning the intercom system: (1) the people using the intercom cannot call the lock operator back if they have a question and (2) the people using the intercom sometimes do not understand what the lock operator is saying because of echoing in the lock. This miscommunication can cause poor interaction between the vessel operator and the lock operator. Not only is this stressful to the lock operator, but it also frus-

trates the vessel operator, especially if he or she is unfamiliar with the locking process.

Recommendation. Improve the intercom system so that two-way communication is possible and the volume of the communication is at a level that minimizes the amount of echoing.

Finding 5

The range of the portable intercom was inadequate.

Discussion. Lock operators reported that the portable intercom did not clearly pick up signals when they went to the break room or other areas. The operators said this was frustrating to them and made them feel they could not leave the control room for long periods of time.

Recommendation. Investigate the availability of portable intercoms with better range.

Finding 6

Lock operators on rotating shifts rotated backward in time instead of the preferable forward in time.

Discussion. Rotating shift work is stressful to the worker. Research indicates that workers who work a few days on one shift and then move to another shift have significantly more visits to a health care provider for personal health care than other workers and complain of a variety of vague but real problems, including digestive trouble, respiratory trouble, anxiety patterns, and sleep disturbances (Fraser 1989).

Recommendation. Rotate operators forward in time.

Other Observations

The following are observations that warrant mention but did not fit into any of the previously discussed categories.

Finding 1

Lock operators spent a lot of time on the telephone.

Discussion. Every lock operator interviewed indicated that he or she spent too much time on the telephone. The lock operators also mentioned that the time they spent on the telephone was the most limiting constraint they encountered when performing their jobs. Most of the frustration experienced by the lock operators occurred because they felt they spent too much time answering questions that did not relate to the passing of vessels through the locks. Most questions they addressed were in reference to the water level in the river, or when cutback of the discharge rate would occur, or whether a particular boat had passed through the lock and when. Many operators stated that the most stressful part of their job was when there was a vessel in the lock and they had to deal with phone calls from people who wanted information, information that could be obtained from other sources.

Recommendations.

- Direct telephone calls to an administrative assistant. Forward the caller to the lock operator only if calls cannot be answered by the administrative assistant.
- Provide an automated message with the answers to frequently asked questions.
- Provide a voicemail message explaining that the lock operator cannot take the call because a vessel is in the lock.

Finding 2

Spider webs were evident on the CCTV cameras.

Discussion. As mentioned previously, the lock operator depends on the CCTV monitors to perform his or her job. Spider webs were observed on the closed-circuit camera. When the sun shone on the webs, the picture displayed on the monitor was distorted. This distortion caused the operator's view to be diminished and subsequently reduced his or her efficiency. Figure 14 shows a typical CCTV camera.

Recommendation. Ensure adequate housekeeping measures are in place to keep the CCTV cameras free of spider webs.

Figure 14. Typical CCTV camera.

Finding 3

Additional lighting is needed outdoors.

Discussion. During the evening hours, the operators did not use the CCTV monitors. Due to the darkness, the cameras did not display a picture with a sufficient amount of detail. In essence, these conditions made the picture displayed on the monitor useless.

Recommendation. Investigate the possibility of lighting portions of the lock to aid the CCTV cameras in displaying a picture that is of use to the lock operator.

Important Considerations

The following considerations may aid the Corps of Engineers in making decisions about the future of lock control design.

Standardization of lock control rooms: The standardizing of lock control rooms should lower the cost of construction and should require only one mock workstation to aid in developing the lock control room. Also with standardization, little or no learning curve should be associated with operating the lock when lock control room operators transfer from one lock to another.

Space requirements for each type of lock control room: In designing their lock control rooms, both the Germans and the Dutch consider (1) adequate room for the equipment currently in use, (2) operator comfort, (3) room for all the equipment needed to support the operator, and (4) room for additional future equipment.

Minimization of clutter in work areas: Site visits to local control rooms revealed that new equipment and furniture often were installed before the old furniture and equipment was removed. This practice created a very cluttered work environment.

Reduction of operators' stress levels: Visitors to the lock and, in particular, pleasure boat operators caused stress for the lock operators.

Role of aesthetics and comfort in the design of lock control rooms: In The Netherlands, it is presumed that lock operators will spend a minimum of 8 hr in the lock control room. Therefore, it is essential that the lock control room be as comfortable as possible to minimize the operators' stress levels.

4 Summary

CERL requested a review of Draft Engineer Manual 1110-2-2610, *Gate Operating Equipment for Navigation Locks and Spillways,* and an ergonomic assessment of navigation lock control rooms and consoles at selected USACE sites and various lock control rooms in The Netherlands and Germany. The primary emphasis of this assessment was to provide ergonomics information to improve the safety, reliability, and efficiency of the lock control room and to help develop standardized guidance for the design of an automated system for operation and control of USACE lock gates.

Between 23 September and 30 October 1998, an ergonomics team from USACHPPM evaluated the lock control rooms and consoles at the Melvin Price Locks and Dam (Illinois), the Bonneville Lock and Dam (Oregon), the Kentucky Lock and Dam (Kentucky), and the Barkley Lock and Dam (Kentucky). From 10 to 19 November 1999, the USACHPPM team evaluated eight European lock control rooms and consoles.

Glare in the control room, excessive telephone calls, control room location, stress, and environmental concerns inside the control room were some of the problems the lock control operators faced. Additionally, many of the problems identified were present at all of the locations surveyed, suggesting that these problems may be prevalent at many other USACE lock control rooms. Surveys of the European locks indicated similar problems. Some of the European sites have implemented controls to minimize or eliminate these problems.

The evaluation team identified deficiencies in the design of the control room and in the design of the console. Lock control operators encountered other stressful conditions as well. The table on the next page summarizes the team's primary findings and recommended solutions.

Table 1. Summary of findings and recommendations.

Findings	Recommendations
Glare in the control room.	Tilt control room windows, reduce number of windows in the control room.
Answering the telephone.	Provide automated telephone service and hands-free telephone operation.
Too many workstations in the control room.	Reduce the number of workstations at which lock operators must work.
Poor location of the control room and control console.	Redesign control room and control console.
Control room can get too hot or cold.	Improve heating and air-conditioning units.
Video cameras get dirty.	Improve housekeeping of video cameras.
Uneducated pleasure boat operators.	Require safety education for pleasure boat operators wanting to use the lock.

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Appendix A: Statement of Work

Ergonomics of Navigation Lock Control Rooms and Consoles

1. BACKGROUND: Manpower reductions and shrinking budgets have made it necessary for the U.S. Army Corps of Engineers to incorporate more automation into the operation of navigation locks. Automation can be used to enhance the "eyes and ears" of the operator and to perform some functions that are currently performed by humans. Automated navigation lock controls and equipment are already used on a limited basis by the Corps, however, their implementation has been piecemeal in nature, and there is currently no standardization. The U.S. Army Construction Engineering Research Laboratory (CERL) is working with St. Louis District to develop standardized guidance for the remote operation and control of Corps of Engineers lock gates. The guidance will be included as a part of Engineer Manual (EM) 1110-2-2610, *Gate Operating Equipment for Navigation Locks and Spillways.*

Navigation lock control rooms are typically located in a tower or building that overlooks the river and lock chambers. The operator sits at a console that includes (1) video monitors that display real-time video of various parts of the locks, (2) computer displays showing gate position, valve position, and many other pieces of operational data, and (3) a variety of buttons that control lock gate functions. Most locks operate both during the day and at night. To date, most of the control room and console designs have been done by electrical engineers with little attention to the comfort and efficiency of the lock operator.

2. OBJECTIVE: The objective of this work is to investigate and provide recommendations on the ergonomics of Corps of Engineers lock gate control rooms and operators' consoles. The recommendations will be incorporated into EM 1110-2-2610.

3. MAJOR REQUIREMENTS: In order to complete this work, it shall be necessary to perform the following tasks:

a. Task 1: Review the section of the draft EM 1110-2-2610 that discusses navigation lock control systems. This document is approximately 50 pages in length.

b. Task 2: Visit two Corps of Engineers lock sites where automated-control systems have been implemented. Interview site personnel and perform the analysis necessary to provide guidance on the ergonomic design of the control room and console. Sites to be visited include Melvin Price Locks and Dam (located in Alton, IL) and another site in Little Rock or Nashville District to be determined.

c. Task 3: Based upon the findings of the site surveys, provide guidance and recommendations that address the following issues and concerns:

(1) Location and type of video monitors that minimize eye and neck strain and that provide the best information for the operator.

(2) Problems with lighting and glare (most control towers, by necessity, have many windows or may be all glass).

(3) Most effective layout of the control room.

(4) Most effective layout of the actual control room.

(5) Most effective layout of the computer displays.

(6) What type of furniture is best.

(7) Noise control (locks can be very noisy places, but the operator still needs to hear what is going on around him or her).

(8) Number of locks that one operator can control before s/he starts losing efficiency and effectiveness.

(9) Any other pertinent issues that may be identified during the site visits.

4. REPORTS: USACHPPM shall provide a report documenting the findings of the tasks listed under "Major Requirements." Five hard copies of the

report shall be provided, as well as one electronic copy in Microsoft Word 97 on 3.5-in. floppy disk.

5. TRAVEL: This work requires the following travel:

a. One trip to Melvin Price Locks and Dam near Alton, IL. Approximately one to two days on-site will be required. Travel dates will be coordinated with the CERL Technical POC.

b. One trip to a lock site in Nashville or Little Rock District. Approximately one to two days on-site will be required. Travel dates will be coordinated with the CERL POC.

6. SCHEDULES and DELIVERABLES: USACHPPM shall submit a draft report to CERL by 31 October 1998. CERL will provide comments by 15 November 1998. USACHPPM shall submit a final report to CERL by 30 November 1998.

Please note report was not delivered to CERL by 30 November 1998 due to an additional trip requested by CERL. The trip was performed in November 1999 and included visits to lock control rooms in Rotterdam, The Netherlands, and Heidelberg, Germany.

Appendix B: Statement of Work Recommendations

1. *Location and type of video monitors that minimize eye and neck strain and that provide the best information for the operator.*

Regarding location, research has shown that people prefer to look downward to close visual targets by inclining the head forward and rotating the eyeballs downward (Kroemer et al. 1994). Researchers also agree that the "normal" line of sight is 10 to 15 degrees below the horizontal plane. This can also be thought of as a resting condition of the eye. Therefore, a display or any other visual target should be placed within a viewing angle of 5 degrees above and 30 degrees below the horizontal plane (Grandjean 1987). With respect to monitors being suspended from a ceiling, the monitors should be no more than 3 ft above the desk level and should be recessed far enough away from the desk to minimize neck extension but still allow for ease of viewing.

With respect to type of video monitor, a larger screen will allow the lock operator to see more detail than a smaller screen. We recommend that the lock operator decide monitor size since this decision will also impact the number of monitors that can be placed in the facility and their location within the workstation. Also, EM 1110-2-2610 states that "in the security industry black and white cameras are the standard because of the higher resolution. However, color camera technology is becoming more accepted. The contrast provided by the color image makes up for the lower resolution" (USACE 1998).

We suggest that color cameras be phased into use at the locks on a trial basis. If the lock operators accept them, then the color cameras should be instituted throughout all locks.

2. *Problems with lighting and glare (most control towers, by necessity, have many windows or may be all glass).*

Glare is produced by brightness within the field of vision that is sufficiently greater than the luminance to which the eyes are adapted so as to cause annoyance, discomfort, or loss in visual performance and visibility (Sanders and McCormick 1993). Although all the control rooms visited had blinds or shades, all the control room employees indicated that more actions needed to be taken to combat the amount of glare to which they were exposed to. Eliminating glare before it reaches the user is the best weapon. This can be accomplished by:

- Determining the minimum amount of windows needed in the room. For example, the Melvin Price Locks had windows in the control room that went from floor to ceiling on all four walls (about 10 ft). Would the control room be better served if the windows went from the ceiling to 4 ft above the floor (about 6 ft)? This would reduce the amount of sunlight entering the room.
- Installing solar insulating film on all windows.
- Installing windows that are angled downward rather than perpendicular to the ground.
- Installing electronically tinted glass (if feasible).
- Providing blinds and shades for all windows.
- Providing antiglare screens to all CCTV and computer monitors as a short-term solution until more permanent solutions are instituted.

3. *Most effective layout of the control room.*

It is impossible to recommend the most effective layout of the control room since many different lock control rooms are used by the Corps of Engineers. However, in terms of centrally located control rooms, the design of the Beatrix Lock in Nieuwegen, The Netherlands, is superior in design to any lock evaluated in the United States by the USACHPPM ergonomics team. The Beatrix Lock control room is functional, comfortable, and is proving to be a stress-free work environment. Appendix E contains more information on the Beatrix Lock control room.

Many factors should be considered when designing a control room. Following are some principles to keep in mind when workstations are to be used by many operators:

- Exclude as few people as possible so that as many people as possible can do the job. This can be easily accomplished by designing for an adjustable range.

- Ensure the work-space envelope (a three-dimensional space within which an individual works, typically the space within which the hands are used) allows all employees to easily reach and access all controls and displays.
- Ensure work-surface heights and seating are adjustable to allow all employees to work in a neutral posture at all times. Furthermore, ensure all adjustable furniture is easily adjustable. Appendix C contains guidelines for increasing the ease of making adjustments.
- Ensure chairs offer appropriate support. Appendix J contains a fact sheet on appropriate chair design.

Following are factors to consider when designing a control room:

- Interview people who are working at the existing workstation to see what redesign ideas they have.
- Visit site locations that have recently used similar workstations to see what design principles and ideas were employed.
- Develop a mock workstation to see if any unforeseen problems arise.

4. *Most effective layout of the actual control panel.*

The most effective layout of the control panel is one that allows for minimal force requirements and easy visual and reach access to all displays and controls for all employees who will operate the control panel. Specific recommendations include:

- Exclude as few people as possible so that as many people as possible can do the job. This includes minimizing reach distances, minimizing mechanical stresses with furniture by providing appropriate clearances, and spacing controls appropriately so no control is inadvertently activated.
- Follow the principles of component arrangement when laying out the control panel: the importance principle, the most important items should be closest to the user; the frequency-of-use principle, the most frequently used items should be easier to access than non-frequently used items; the functional principle, all items that perform a specific function should be grouped together; and the sequence-of-use principle, all items used in sequence should be located near each other in sequence.

In general, when designing workplaces that involve displays and controls, the following guideline may be useful (Sanders and McCormick 1993):

- First priority: Primary visual tasks.

- Second priority: Primary controls that interact with primary visual tasks.
- Third priority: Control-display relationships (put controls near associated displays, compatible movement relationships, etc).
- Fourth priority: Arrangement of elements to be used in sequence.
- Fifth priority: Convenient location of elements that are used frequently.
- Sixth priority: Consistency with other layouts within the system or in other systems.

Lastly, it is suggested that a mock workstation be built once all data are collected. This will allow end users to test their workstation and allow for one last chance to remove any flaws in the system before the workstation is put in place.

5. *Most effective layout of the computer displays.*

Field testing of different layout designs is the best way to determine the most effective layout of a computer display. An important concept is compatibility. Compatibility refers to the degree to which relationships are consistent with human expectations. Where compatibility relationships are designed into the system, (1) learning is faster, (2) reaction time is faster, (3) fewer errors are made, and (4) user satisfaction is higher (Sanders and McCormick 1993).

6. *The adequacy of the furniture used.*

Control room operators do not necessarily sit down when operating the console. Also, body sizes and shapes vary widely among the employees who operate the console. Furthermore, the only piece of adjustable furniture in the room is the chair. Given these factors it is very unlikely that any of the control room employees work in a comfortable or efficient manner. To ensure better comfort and efficiency at a workstation where multiple users operate the equipment, the general principle of designing for the range should be employed.

- Certain pieces of equipment can be designed so that they can be adjusted to fit the individuals who use them. A well-designed, fully adjustable chair will promote appropriate body postures, maintain adequate circulation in the body, and reduce the amount of strain on the spine, as well as allow freedom of movement. An adjustable desk height will provide even more freedom for the operator to adapt the work environment to meet his or her individual needs based on size, personal preferences, etc.

- Provide chairs and desks that can be adjusted easily to meet the needs of the 5th percentile female to the 95th percentile male whether operators are standing or sitting.
- Ensure adequate leg clearance under the control panel.
- Ensure the depth of the control panel allows for the 5th percentile female to easily reach all controls.

7. *Noise control (locks can be very noisy places, but the operator still needs to hear what is going on around him or her).*

The lock operators interviewed did not consider noise to be an on-the-job problem. Our observations indicated that the internal noise in a lock control room was generated mainly by speech communication, air-conditioning, and other equipment and not associated with the vessels passing through the locks. We recommend replacing noisy equipment with quieter equipment when noise is a problem (Berger et al. 1988).

In areas where the noise is intense due to the passing of vessels, greater preventive measures may need to take place. For example, consider designing the lock control room so that the attenuation of airborne sound can be achieved. The building must be constructed with materials impervious to airflow, be lined with sound-absorbing material, and have tight-fitting joints so that all cracks and openings are tightly sealed (Berger et al. 1988).

8. *Number of locks that one operator can control before s/he starts losing efficiency and effectiveness.*

A survey of lock operators did not provide much insight relative to the number of locks one operator can effectively control. The lock operators indicated that a number of influential factors need to be considered, such as the proficiency of the vessel operator, the type of vessels in line to be locked, and time constraints placed on the operators (e.g., phone use or weather conditions). Most lock operators indicated that they were comfortable handling no more than 8 to 12 vessels in line at one time. Also, some lock operators were reluctant to speculate since they had no idea what it would be like to operate more than one lock at a time.

9. *Any other pertinent issues that may be identified during the site visits.*

Lock operators were overwhelmed by the number of phone calls to which they must respond.

Lock operators felt the security within the lock compound needed to be improved.

The intercoms used in the lock were not appropriate. Communication was difficult due to echoing in the lock.

Pleasure boat operators caused more stress to the lock operators than barge operators.

There were a number of spider webs at the locks. The webs distorted the view on the monitors.

Appendix C: Ergonomic Design Principles

Types of Movement

Discrete movements involve a single reaching movement to a stationary target, such as reaching for a control or pointing to a word on a computer screen. Discrete movements may be made with or without visual control.

Repetitive movements involve a repetition of a single movement to a stationary target or targets. Examples include hammering a nail or tapping a cursor key on a computer keyboard.

Sequential movements involve discrete movements to a number of stationary targets regularly or irregularly spaced. Examples include typewriting or reaching for parts in various stack bins.

Continuous movements involve movements that require muscular control adjustments of some degree during the movement, as in operating the steering wheel of a car or guiding a piece of wood through a band saw.

Static positioning is maintaining a specific position of a body member for a period of time. Strictly speaking, this is not a movement, but rather the absence of movement. Examples include holding a part in one hand while soldering, or holding a needle to thread it.

Use of Anthropometric Data

In the use of anthropometric data for designing something, the data should be reasonably representative of the population that would use the item. In many instances, the population of interest consists of "people at large," implying that the design features must accommodate a broad spectrum of people. When items are designed for specific groups (such as adult females, children, the elderly, foot-

football players, the handicapped, etc.), the data used should be specific for such groups in the country or culture in question. Appropriate data are not yet available, however, for many specific groups.

Principles in the Application of Anthropometric Data

There are three general principles for applying anthropometric data to specific design problems. Each principle applies to a different type of situation.

Design for Extreme Individuals

In designing certain features of our built physical world, one should try to accommodate all (or virtually all) the population in question. In some circumstances, a specific design dimension or feature is a limiting factor that might restrict the use of the facility for some people; that limiting factor can dictate either a *maximum* or *minimum* value of the population variable or characteristic in question.

Designing for the *maximum* population value is the appropriate strategy if a given maximum (high) value of some design feature should accommodate all (or virtually all) people. Examples include heights of doorways, sizes of escape hatches on military aircraft, and strength of supporting devices (such as a trapeze, rope ladder, or workbench). In turn, designing for the *minimum* (low) value of some design feature has to accommodate all (or virtually all) people. Examples include the distance of a control button from the operator and the force required to operate the control.

Usually there are reasons for accommodating most, but not 100 percent, of the population. For example, it is not reasonable to have all doorways 9 ft (2.7 m) high to accommodate circus giants. Thus, it frequently is the practice to use the 95th male and 5th female percentiles of the distributions of relevant population characteristics as the maximum and minimum design parameters.

Designing for Adjustable Range

Certain features of equipment and facilities can be designed so they can be adjusted to the individuals who use them. Some examples are automobile seats, office chairs, desk heights, and footrests. In the design of such equipment, it is frequently the practice to provide for adjustments to cover the range from the

5th percentile female to the 95th percentile male of the relevant population characteristic (sitting height, arm reach, etc.). The use of such a range is especially relevant if there could be technical problems in trying to accommodate the very extreme cases (i.e., 100 percent of the population). Frequently the technical problems involved in accommodating the extreme cases are disproportionate to the advantages gained in doing so. Note that using a range from the 5th percentile female to the 95th percentile male will result in accommodating 95 percent of a 50/50/male/female population, not 90 percent, because of the overlap between male and female body dimensions. Generally, designing for an adjustable range is the preferred method of design, but, of course, it is not always possible.

Designing for the Average

First of all, there is no "average" individual. A person may be average on one or two body dimensions, but, because there are no perfect correlations, it is virtually impossible to find anyone who is average on more than a few dimensions. Often, designers design for the average as a cop-out so that they do not have to deal with the complexity of anthropometric data. This is not to say that one should never design for the average. On the contrary, a thorough analysis of the situation may prove that an average value is acceptable. Such a situation would probably involve noncritical work where it is not appropriate to design for an extreme and where adjustability is impractical. For example, a checkout counter at a supermarket built for the average customer would probably inconvenience the majority of the customers less than one built for either jockey Willy Shoemaker or basketball player Wilt Chamberlain. Designing for the average should only be done after careful consideration of the situation and never as an easy way out.

Compatibility

Compatibility refers to the degree to which relationships are consistent with human expectations. Where compatibility relationships are designed into the system, (1) learning is faster, (2) reaction time is faster, (3) fewer errors are made, and (4) user satisfaction is higher (Sanders and McCormick 1993).

For a complete discussion of ergonomic design principles consult the following reference books:

Grandjean, Etienne, *Ergonomics in Computerized Offices* (Taylor & Francis, Inc., NY, 1987) (ISBN No. 0-85066-349-0).

Konz, Stephan, *Work Design - Industrial Ergonomics (4th Edition)* (Publishing Horizons, Inc.; Scottsdale, AZ, 1995) (ISBN No. 0-942280-65-2).

Sanders, M.S. and E.J. McCormick, *Human Factors in Engineering and Design* (McGraw-Hill, Inc., NY, 1993) (ISBN No. 0-07-054901-X).

Appendix D: Draft Engineer Manual (EM) 1110-2-2610 Comments

As stated in paragraph 4-2c.(1), "*This manual is an attempt to provide general guidelines to stimulate ideas within designers when developing a new lock control system.*" The comments made with regard to EM 1110-2-2610, *Gate Operating Equipment for Navigation Locks and Spillways*, will be general in nature to aid the designers when they develop a new lock control system.

4-2.c.(1)(a)...*PLC Manual Controls. "The manual controls should be simple and ergonomically designed with good visual feedback devices such as pilot lights and/or on-screen graphics."*

There are two issues here, manual controls design and on-screen graphics. For manual control device design, the following guidelines should be followed:

Hand pushbuttons: The surface should be concave or should provide friction. Preferably, there should be an audible click when the push button is activated. Use elastic resistance plus slight sliding friction starting low and building up rapidly to a sudden drop. Minimize viscous dampening and inertial resistance.

Toggle switch: Use elastic resistance that builds up and then decreases as position is approached. Minimize frictional and inertial resistance.

Rotary selector switch: Provide a detent for each control position (setting). Use elastic resistance that builds up and then decreases as the detent is approached. Minimize friction and inertial resistance. Separation of detents should be at least ¼ in. (6 mm).

Knob: Preferably code by shape if knob is used without vision. The type of desirable resistance depends on performance requirements.

For visual feedback devices, it is important for the designer to know the type of information that is being displayed. For example, is the user interested in the

approximate value of some continuously changing variable (such as water depth or temperature)? If so, then a **qualitative visual display** would be appropriate. If the user just needs to know if a value is in a "normal range," then a color-coded **check reading display** would be appropriate (such as a tachometer in an automobile with red at the high end of the scale representing danger). Furthermore, a **status indicator** would be useful to determine if a condition is normal or abnormal (such as on or off or a traffic light stop, caution, and go).

If **signal and warning lights** are to be used, then certain questions need to be answered such as:

When should the lights be used? To warn of an actual or a potential dangerous condition.

How many warning lights should be used? Ordinarily only one. (If several warning lights are required, use a master warning or caution light and a word panel to indicate a specific danger condition.)

Should lights be steady state or flashing? If the light is to represent a continuous, ongoing condition, use a steady-state light unless the condition is especially hazardous; continuous flashing lights can be distracting. To represent occasional emergencies or new conditions, use a flashing light.

Flash rate: If flashing lights are used, flash rates should be from about 3 to 10 per second (4 is best) with equal intervals of light and dark. If different flash rates are to represent different levels of some variable, use no more than three different rates.

Warning light intensity: The light should be at least twice as bright as the immediate background.

Location: The warning light should be within 30 degrees of the operator's normal line of sight.

Color: Warning lights are normally red because red means danger to most people. (Other signal lights in the area should be colors other than red.)

Size: Warning lights should be subtended at least 1 degree of visual angle.

Finally, ensure the backup control box buttons are the same as the control room box. The layout and design of the buttons should meet all user stereotypes.

4-2.c.(1)(b)...*Semi-Automated Lockage. "This process requires only 1 person to operate a lock and frees that operator up to enter lockage data, arrange queues, operate tainter gates, operate adjacent locks, and other duties necessary to operate a facility."*

This may be true. Before semi-operated lockage is instituted, however, determine all the other duties the operator will face and the time constraints placed on the operator. Seemingly minor tasks, like manning the telephones, could take up more operator time than estimated.

4-2.c.(2)(c)...*Traffic. "The new control system has to be designed with the current traffic and future traffic projections in mind. Automation and remote control are two features that can address these needs."*

Automation can be helpful to the lock operator, but it is not the only piece of the puzzle. Other questions need to be answered to determine if only one operator is needed at the lock. In addition to current and future traffic needs, questions relating to the operators' other assumed duties and the type of traffic that is going to be experienced (high volumes during the different seasons, types of craft, etc.) need to be addressed. During the survey, lock operators found locking pleasure craft to be more stressful than locking barges.

4-2.c.(3)...*Control Rooms. "Control rooms should be designed with the needs of the operator in mind. From an equipment standpoint, locations of consoles, CCTV monitors and consoles, maritime radios, PA systems, IPC monitors, printers, and vessel logging computers can be located essentially anywhere."*

The needs of the operators in one control room will be different from those of the operators in another control room. A statement is needed that speaks to how best to determine what the needs of the operator are. Design principles that deal with the arrangement of components within a physical space (importance principle, frequency of use principle, functional principle, and sequence of use principle) need to be addressed. Remember, the design of the control room should meet almost, if not all, the needs of the operators.

4-2.c.(3)(a)...*Automated Systems. "Where possible, direct visibility to the lock should always be a consideration."*

During the site visits to the locks, all lock operators interviewed and observed preferred to look at the vessels entering the lock rather than depend on the CCTV monitors. It is recommended that the wording in this paragraph be stronger. Direct visibility to the lock should be a requirement, not simply a consideration.

4-2.c.(3)(a)...*Automated Systems. "In an automated system having centralized single operator control, the CCTV monitors become the main focal point of the operator's attention. These should be positioned to give the operator not only convenient access, but orientation of the actual lock equipment so quick reference can be made when examining the monitors. In other words, views that are downstream and made looking to the landside of the lock should be the same when looking at the CCTV monitors."*

Centralized lock control rooms may not afford the operator the opportunity to easily look out the window and view the progress of the vessel in the lock. Therefore, every opportunity should be taken when installing CCTV cameras to mimic the views on the CCTV monitors that the operators would have if the control room were located next to the lock.

4-2.c.(3)(b)...*Visibility. "In an automated centralized control room, consider positioning and orienting control consoles and CCTV monitors so that direct visibility is available without the operator having to leave the console area, or continually rotate 90 to 180 degrees to see the lock approach areas.*

Interviews with lock operators indicated they wanted this feature incorporated into the design of the locks. From an ergonomics perspective, direct visibility with the head and neck remaining in a neutral posture is the preferred design approach and will lead to maximum worker efficiency.

4-2.c.(3)(b)...*Visibility. "In the future it is very likely that there will be less work force at the locks, and operators could be saddled with other maintenance type duties to be performed simultaneously with vessel lockages. Designers need to consider and plan for this by making the system as convenient and yet safe to operate, increasing the efficiency of the project."*

Interviews with lock operators indicated that some of them perform maintenance-type duties simultaneously with vessel lockages (Barkley Lock). In this sense, the "future" is here. It is suggested that plans be made to design systems to require less operator attention so that, in addition to locking vessels, the

newer duties lock operators must perform can be handled with a minimum loss of efficiency.

4-2.c.(3)(c)...*Automated Systems. "Administrative areas, maintenance areas, and visitor access should be kept separate from the control room in order to minimize distractions to the operator. A reasonably accessible break room with restroom facilities, stove, microwave, and refrigerator should be considered when possible. Take under review the possibility of providing a means for fresh air ventilation during pleasant weather. These will all help to increase the overall efficiency of the lock."*

Interviews with lock operators from the Melvin Price Locks indicated a sense of operators isolation from the rest of the employees who work in different buildings. Lock operators feel like "second-class citizens" when amenities provided to the rest of the employees are not provided to them (i.e., lockers are provided in the main building, but not in the control room). Care should be exercised when determining what is and is not included in the centralized control rooms.

The idea of providing fresh air ventilation is excellent. This will provide the lock operators with more flexibility to regulate their thermal environment.

4-2.c.(3)(e)...*Operating Consoles. "The operating consoles are the actual point of interface between a lock operator and a computerized control system. A design engineer should spend significant time reviewing all of the factors that make a control system operator interface user friendly, efficient, convenient, and most of all safe."*

No guidance is provided as to how to accomplish all these objectives. A standard that addresses the factors that make up a user-friendly system needs to be developed. Specific questions include:

- Is the workstation going to be designed for sitting, standing, or both?
- What features of the workstation are going to be adjustable?
- What is the optimum CCTV monitor location?
- Which design principles are most appropriate for the console design and should take precedence?

4-2.c.(3)(e)...*Closed-circuit Television System. "It is imperative to locate these where they will be convenient to view. Factors such as glare, operator comfort,*

viewing angle, and accessibility should all be considered when placing CCTV monitors in a control console."

The above statement is true. Remember, operator comfort will vary from operator to operator. Thus, adjustability of the monitors needs to be addressed. By allowing each operator to adjust the monitor height, angle, and viewing distance to any position, operators are ensured of working in a neutral posture, which is the most comfortable and efficient work posture.

The issue of glare is best addressed through better window design and not monitor placement.

4-2.c.(3)(e)...*IPC Control Network..."the IPC monitors should be located where, aside from the CCTV monitors, they are the easiest and most convenient control system component to monitor. Because an operator will often be accomplishing other duties simultaneously with operating the lock equipment, IPC monitors that are located above the CCTV monitors and at approximately shoulder level will provide a good viewing angle for the operator."*

Issues need to be addressed before this recommendation becomes instituted. Is this recommendation based on a sitting or standing shoulder height? Also, we have interviewed personnel who range in height from 5'5" to 6'3", so whose shoulder height are we talking about? Will placing the IPC monitors above the CCTV monitors alter or reduce the lock view? This recommendation as is does not seem feasible.

4-2.c.(3)(e)...*Vessel Logging PC. "An operator will actually spend more time at this computer than at the lock operating IPC network workstations. Therefore, this PC should be located where the operator can sit down and log information; however, it should be convenient for the operator to access."*

Interviews verified this claim. Yet the furniture provided to the lock operators for this type of computer work was poor. Perhaps the issue that needs to be addressed more than the PC location is the furniture provided to the lock operator to operate the PC.

4-2.c.(3)(e)...*Marine Band Radio. "An operator will spend significant time on the marine radio arranging queues and acquiring vessel cargo information. Lock operators will likely move the radio to several different locations on the console while they are getting used to the new system. For this reason, it is probably not a*

good idea to provide a permanent location for mounting the radio. Rather provide means to move the radio to any location on the console allowing the operators, after they are accustomed to the new control system, to station the radio where it is most convenient for them."

It is suggested that the purchase or use of a wireless microphone (i.e., cordless telephone design vs. a walkie-talkie or headset) be investigated. This will give the lock operator more freedom to move about the control room. We are not adverse to using a walkie-talkie, but the lock operators indicated their range was not as good as the radio set.

4-2.c.(3)(e)...*Telephone. "Multiple lines, zone ringing, and paging, and other features will provide even more convenience and efficiencies to the lock operators and will likely cost less than separate phone and PA systems."*

It is true that telephone systems today are more advanced than ever. However, the biggest complaint the lock operators had about their jobs was the amount of time they had to spend on the telephone. It is suggested that, if telephone systems are consolidated, no additional duties are added to the lock operator's job. It would be best if the consolidation of telephone lines resulted in a decrease in the amount of time lock operators must spend on the telephone in order to allow them to give the utmost attention to ensuring safe and efficient passage of traffic through the locks.

4-2.d.(3)(b)(ii)...*Camera Requirements. "Another question to be answered by the designer is the use of color cameras. In the security industry black and white cameras are the standard because of the higher resolution. However, color camera technology is becoming more accepted. The contrast provided by the color image makes up for the lower resolution.*

The biggest problem that the lock operators faced regarding the cameras used was the inability of the cameras to provide enough contrast when it was exceedingly sunny. Under these conditions, there were portions of the lock that were too bright or too shady. Picture enhancement to allow all areas of the lock to be viewed under sunny conditions needs to be addressed by the designer.

4-2.d.(3)(b)(iii)...*Lighting Conditions. "For a CCTV system to work properly, adequate lighting must be provided. The sensitivity of a camera refers to its ability to produce a useable image given a minimum lighting level. The CCTV market contains many cameras with various sensitivities, but the designer must re-*

member that just because a manufacturer's specification sheet states a certain sensitivity, it does not mean the picture will be usable at that level."

Care needs to be exercised when determining what the light level will be. Also, to allow the CCTV camera to detect an image, the vessel operator's eyes need to adjust to the highly lit area. During the day, the eyes' photopic system (daylight vision) is used. During the night the eyes' scotopic system (night vision) is used. Partial adaptation of the eyes from a dark background to a lit source takes several minutes. It is therefore important to balance the requirements of the camera with the needs of the vessel operator. One of the lock operators suggested using red lights to light up the lock at night to preserve the night vision of the vessel operator.

4-2.d.(3)(b)(vii)...*Camera Housing. "Camera housings protect the camera and lens from tampering when used indoors and also from the elements when used outdoors. Accessories may be available for the housing to control the inside temperature, block the sun, and a wiper to keep the viewing window clear. A thermostat controls the heater inside the housing. Heating the unit keeps the viewing window clear and prevents condensation. Sun visors eliminate some of the problems associated with the glare produced by the sun. The visor also helps keep the rain off the viewing window."*

During site surveys spider webs were observed on the camera housing (visor). It is suggested that, if a camera housing is used, some type of cleaning schedule be instituted to ensure a minimum of problems when operators are viewing the CCTV monitors.

Appendix E: Notes From European Site Visits

Gorinchem Lock Control Center, The Netherlands

Monday, 1st Lock Location

This control center is the last of this generation of lock control rooms. One operator does one job. He or she operates a single lock centrally. Eventually the operator will be able to control multiple locks from one central location. This control room is nicely designed, but it pales in comparison to the Beatrix Lock control room.

Ceilings, walls, and furniture all have a matte finish.

A foot pedal operates the control operator's microphone, leaving the operator's hands free for writing or keyboarding information.

Operators do not like the high bank of monitors mounted to the ceiling.

The main work surface is designed for the operator to lean on so he or she can look into the river.

Chairs are very good. The intent is to provide the best chairs possible in order to save money by not providing adjustable desks.

Beatrix Lock, Nieuwegen (Near Uttecht), The Netherlands

Monday, 2nd Lock Location

This lock control room is the newest, less than 5 years old. It has been called the "new generation" of lock control rooms. In the opinion of the ergonomist, it is the crème de la crème of all the rooms visited.

All furniture is dark in color and has a matte finish (to reduce glare).

Windows are only 48 in. high.

Monitor bank (mounted to ceiling) is curved to aid in ease of viewing.

Ceiling-mounted monitors are 3 ft above the desk surface.

All indoor shades and outdoor baffles can be remotely controlled.

Desks are about 13 ft long.

The CCTV and lock monitors use 25-in. diagonal screens.

Monitors rest on a stand behind the desk surface, which aides in cable management. (The Corps of Engineers may be able to use this idea and make the monitors height-adjustable.)

Tables are designed so that the user can lean forward on the desk and look over the monitors to see a vessel in the lock.

All functions that can be performed remotely can be accomplished using one computer (monitors, shades, baffles, radio, etc.).

Heel Lock Complex, The Netherlands

Monday, 3rd Lock Location

This lock control room is older in design than the first two lock control rooms.

The top half of walls are light.

The furniture is light.

The walls have a matte finish.

The monitors are low.

The lighting has been modified to make it adjustable (i.e., on dimmer switches). The on/off florescent lighting is gone.

Task lighting is good.

The chair is very good.

The lack of indoor shades makes a big difference in the amount of light that enters.

Volkerak Sluizen, Rotterdam, The Netherlands

Tuesday, 1st Lock Location

This lock control room is approximately 10 years old. The control panel is reminiscent of the Bonneville Lock Control Room. Monitor location is high, like the Melvin Price Locks Control Room.

The desks are not adjustable.

The chairs look good.

The furniture is light in color.

The walls are light in color.

The windows do not extend from floor to ceiling.

There are indoor shades, tilted windows, and windows on all sides of the control room.

Overall, the room is reminiscent of the Melvin Price Locks.

Koblenz, Germany

Thursday, 1st Lock Location

This control room is not very modern. The locks were built in 1941 and 1949. The new control room was built in 1951.

The ceiling was replaced. The new ceiling is made of wood, which helps to reduce glare and is aesthetically pleasing. Other creature comforts include a fancy couch, a stereo, and good heaters to regulate heat easily.

The air conditioning is not thermostat-regulated. The room gets too cold. The intent is to get a unit with a better feedback mechanism.

Plenty of space has been devoted to the control room — approximately 470 sq ft for one operator.

Lehmen, Germany

Thursday, 2nd Lock Location

Style/technology is similar to the Koblenz locks control room.

Notable features include plenty of task lighting, a good chair, and good baffles on the overhead lights.

All software was trackball-driven vs. mouse-driven.

Monitor locations were too high.

There were two rooms side by side, one to work in and the other for breaks.

Oberwesel, Germany

Thursday, 3rd Location, Traffic Control Room

The room is light in color with multiple types of overhead lighting. All lights are on a dimmer switch.

Monitors are on stands behind the work desks. Stands can move from side to side, but not up and down.

Computer program ensures all views seen by the operator on the monitor are on the same scale. Software is trackball driven. To minimize confusion, there is a clear distinction of tasks.

There are plenty of blinds and shades.

Heidelberg, Germany

Friday, 1st Location, Lock Control Room

The room is designed for one person.

The room is approximately 300 sq ft.

There is good cable management.

There is enough room to add new equipment.

The CCTV location is too high.

Summary of Findings From European Site Visits

As a whole, the lock control room designs found in The Netherlands are superior to the designs found in Germany. Therefore, only the lock control rooms evaluated in The Netherlands will be addressed here.

The design of the Beatrix Lock in Nieuwegen was superior in design to other lock control rooms in The Netherlands. The Beatrix Lock Control Room design contains the best features of the previous generation of lock control rooms (i.e., the Gorinchem Lock Control Center). It is very functional, comfortable, and stress free. Figures E1-E6 show notable design features in the Beatrix Lock Control Room.

Following are some notable design features of the Beatrix Lock Control Room. We recommend that the Corps of Engineers incorporate these features in the design of all lock control rooms.

- All furniture, walls, and ceilings are dark in color and have a matte finish to reduce glare.
- Windows extend from the ceiling and drop down 48 in. rather than extending the entire height of the wall. This design reduces the thermal load and the amount of light entering the control room.
- The monitor bank (mounted to the ceiling) is curved for ease of viewing. This reduces the amount of neck twisting needed to view all of the monitors.

- The ceiling-mounted monitors are 3 ft above the desk surface. This is a significant improvement compared to the overhead location of CCTV monitors found at other sites.
- All functions that can be performed remotely can be accomplished using one computer (locks, shades, baffles, radio, etc.).
- The 25-in. diagonal screens used for CCTV and lock monitors help the operator to view all activity in the lock.
- Monitors rest on a stand behind the desk surface, which frees desk space for keyboards, microphones, telephones, and other pieces of equipment. This also aids in cable management (i.e., neat storage of computer cables). CERL may be able to make the stands height-adjustable to allow the lock operators greater flexibility with regard to monitor placement.
- Tables are designed so the user can lean forward on the desk and look over the monitors to see a vessel in the lock.
- Desks are about 13-ft long, providing the lock operator with plenty of room to store all equipment at one desk.

A foot pedal controls the radio, which allows the lock operator to communicate with vessels in the lock while keeping both hands free to enter data in the computer.

In addition to implementing engineering controls, another goal was to eliminate or reduce stress in the work environment of the Beatrix Lock operators. Because the lock operator spends a great deal of time in one room, the room was designed and equipped to make the time spent in that room as pleasant as possible during both peak and off-peak (less busy) times. The large control room, approximately 1000 sq ft, is used by two and sometimes three lock control room operators. Comfort features include a kitchen area, a television with VCR, a stereo system, and couches.

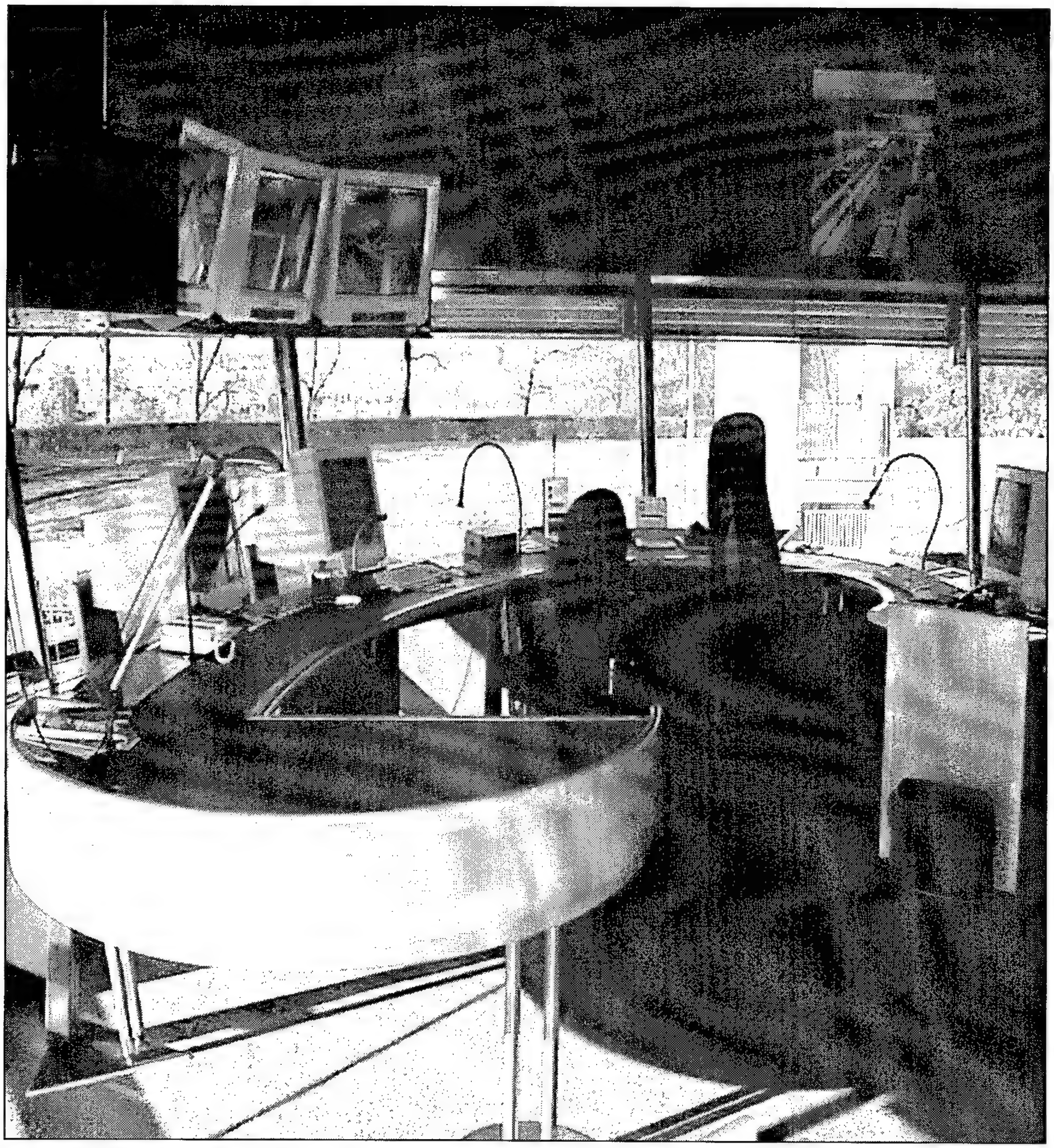


Figure E1. Beatrix Lock Control Room workstation.

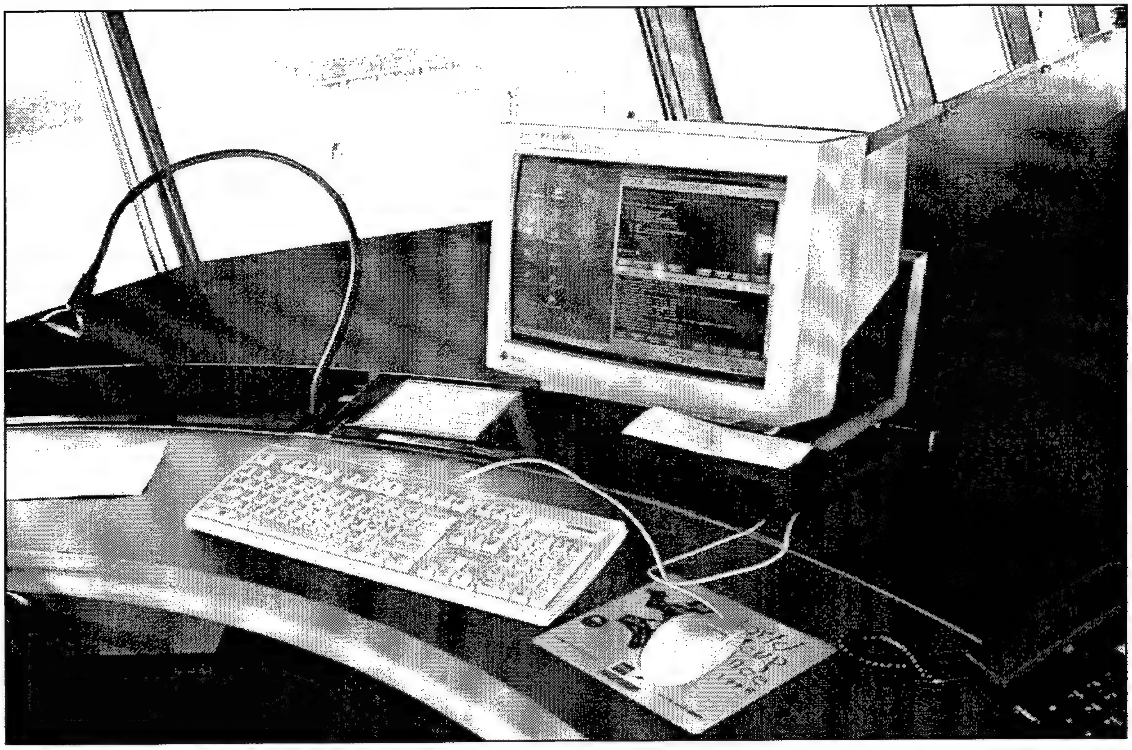


Figure E2. Beatrix Lock Control Room computer setup.

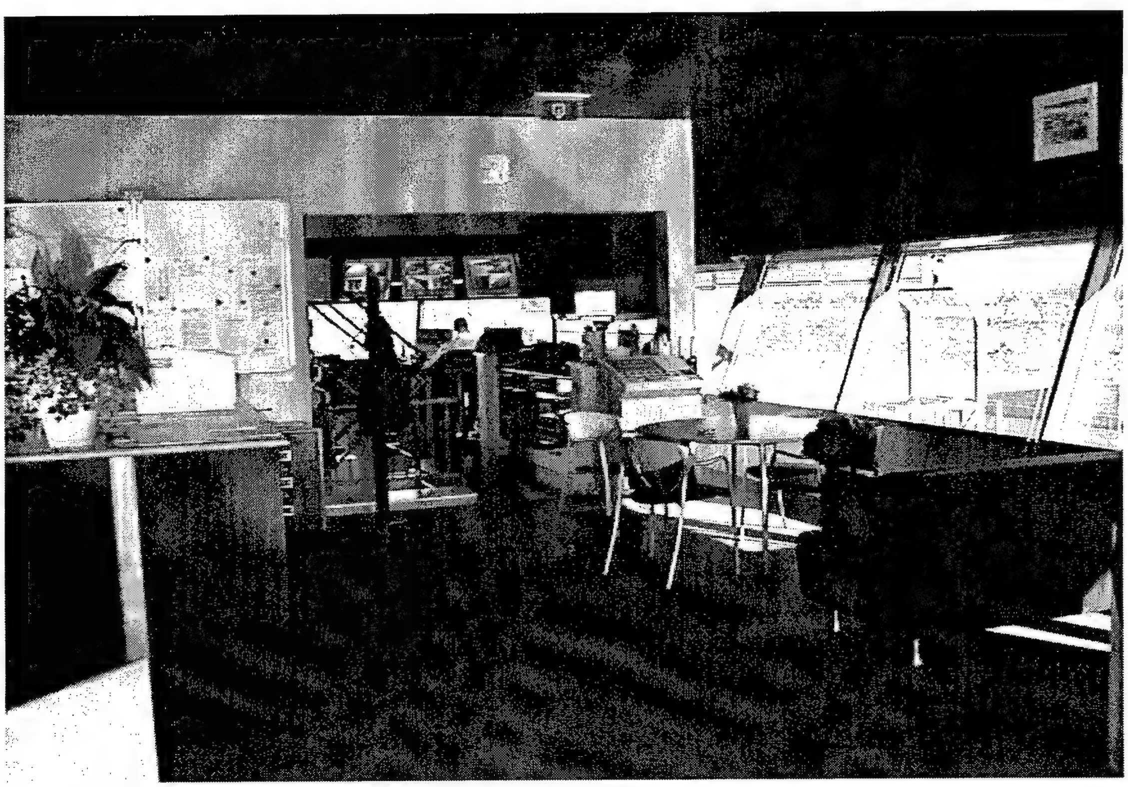


Figure E3. Beatrix Lock Control Room break area.

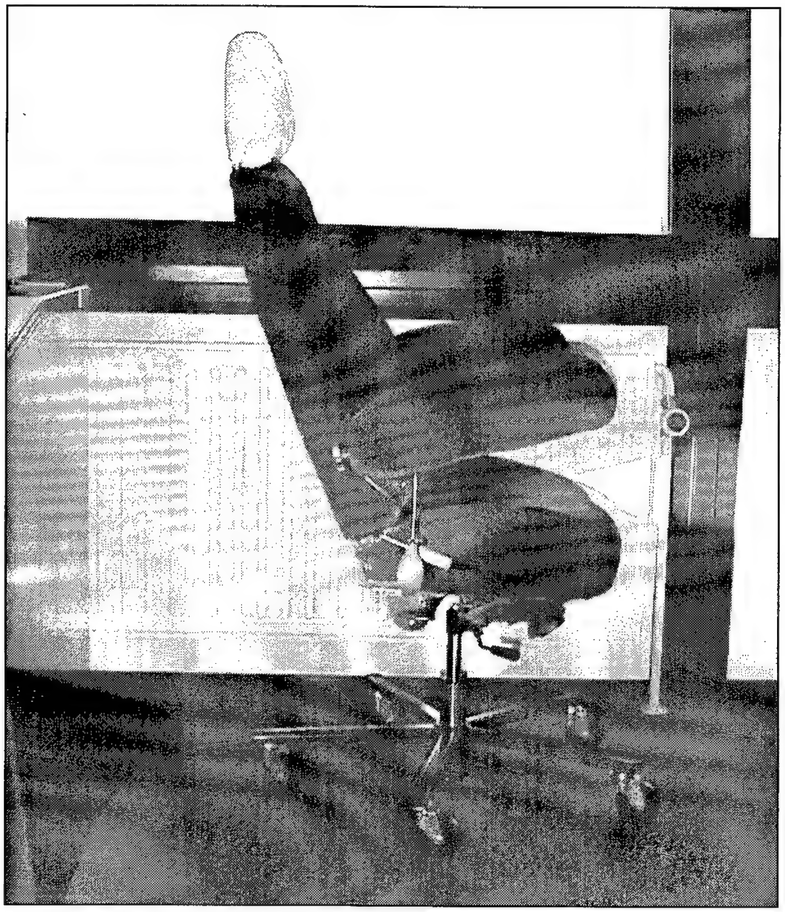


Figure E4. Typical chair found in a lock control room.

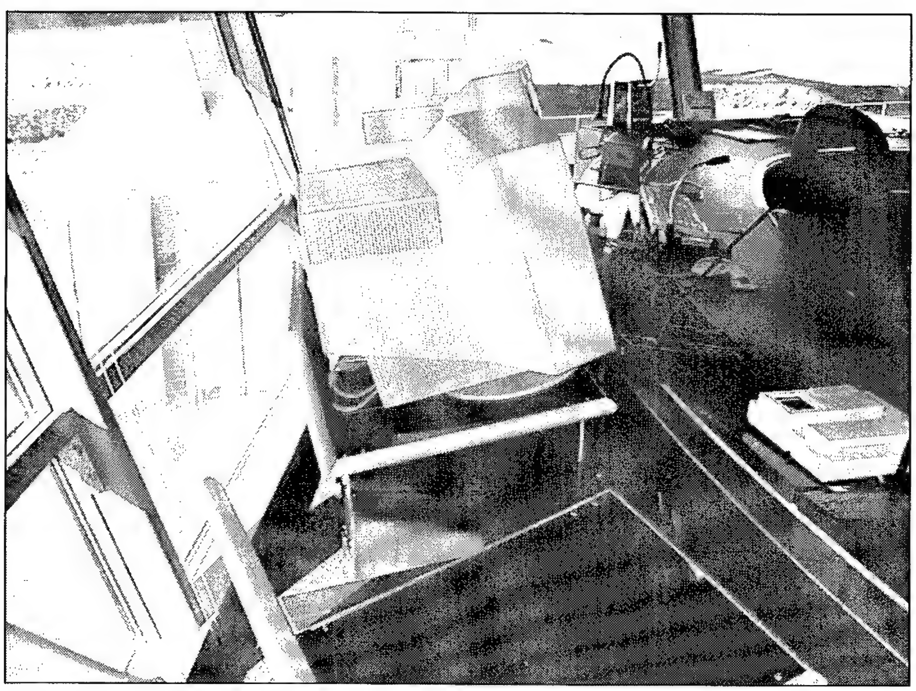


Figure E5. Monitor stand in use in the Beatrix Lock Control Room.

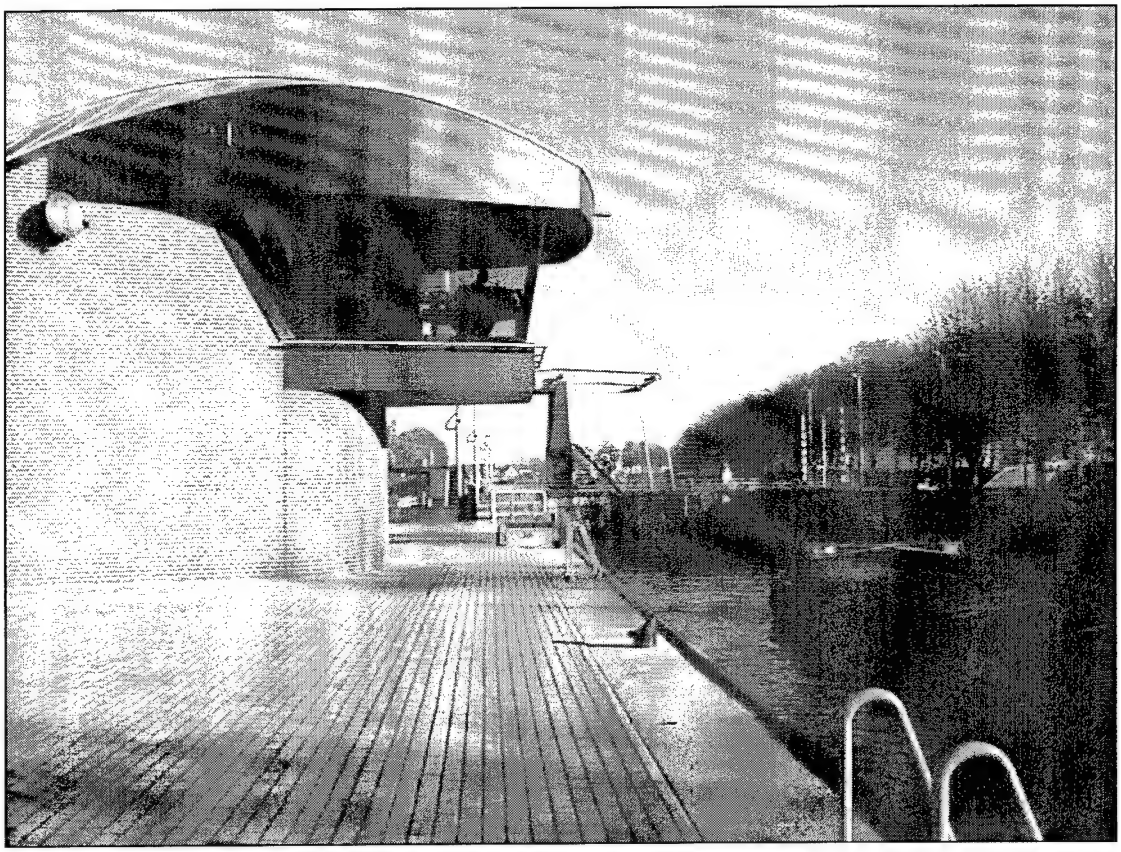


Figure E6. Outdoor view of the Beatrix Lock Control Room.

Appendix F: Sample JRPD Survey Form

Department of Defense
Job Requirements and Physical Demands Survey

GENERAL INSTRUCTIONS

- The survey will take approximately 45 minutes to complete.
- Answer all questions to the best of your abilities.
- Please hand in all forms when completed.

MARKING INSTRUCTIONS

- Use only a No. 2 pencil or a pen with blue or black ink.
- Do not use pens with ink that soaks through the paper.
- Make solid marks that fill the response area completely.
- Make no stray marks on this form.

CORRECT: ● INCORRECT: ✓ ⊗ ○

Background Information

1. Workplace Identifier
Do not mark unless instructed.

2. Date
MONTH | DAY | YEAR

3. Age
○ Under 21
○ 21-25
○ 26-30
○ 31-35
○ 36-40
○ 41-45
○ 46-50
○ 51-55
○ 56-60
○ 60-65
○ over 65

4. Gender
○ Female
○ Male

5. Length of time at this base?
○ Under 1 Year
○ 1-5 Years
○ 6-10 Years
○ 11-15 Years
○ 16-20 Years
○ Over 20 Years

6. Length of time at current job?
○ Under 1 Year
○ 1-5 Years
○ 6-10 Years
○ 11-15 Years
○ 16-20 Years
○ Over 20 Years

7. Have you completed this questionnaire before?
○ Yes
○ No

8. Department of Defense Component
○ Air Force
○ Army
○ Navy
○ Marines
○ Army & Air Force Exchange Agency
○ Defense Commissary Agency
○ Defense Logistics Agency
○ National Security Agency
○ Other DOD Component

9. Service Component
○ Civilian Employee
○ Contractor
○ Foreign National

Military Only:
○ Guard
○ Regular
○ Reserve

PLEASE DO NOT WRITE IN THIS AREA

04468

Do not mark unless instructed.

Location Information

10. COMMAND

11. INSTALLATION (Base name)

12. ACTIVITY

★U.S. GOVERNMENT PRINTING OFFICE: 1998-441-727 EW-221205-1

Organization Information

13. BUILDING

14. ROOM

15. Job Code
Civilian (Job Series)
Example: 0 0 8 0 3
(Safety Engineer)
Army/Marines (MOS)
Example: 7 0 4 1
Air Force (AFSC)
Example: 1 A 1 0 0
Navy NOBC (Officers)
NEC (Enlisted)
Example: 9 5 0 2

16. Pay Plan and Grade
Examples:
GS-5 would be: G S 0 5
WG-3 would be: W G 0 3
E-3 (Enlisted) would be: E 0 3
O-4 (Officer) would be: O 0 4

A. Description of Work

This section asks you to describe what is involved in your job. Indicate how long you do this work on approximately a daily basis.

Shoulder / Neck

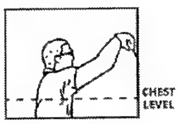


Figure A

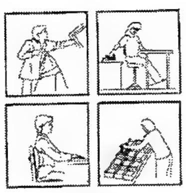


Figure B

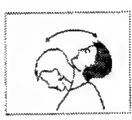


Figure C

Figure D

	NEVER	0-2 HOURS	2-4 HOURS	4-8 HOURS
1. I work with my hands at or above chest level. *(Figure A)*	○	○	○	○
2. To get to or to do my work, I must lay on my back or side and work with my arms up	○	○	○	○
3. I must hold or carry materials (or large stacks of files) during the course of my work	○	○	○	○
4. I force or yank components or work objects in order to complete a task	○	○	○	○
5. I reach or hold my arms in front of or behind my body (e.g., using a keyboard, filing, handling parts, performing inspection tasks, pushing or pulling cards, etc.). *(Figure B)*	○	○	○	○
6. My neck is tipped forward or backward when I work. *(Figure C)*	○	○	○	○
7. I cradle a phone or other device between my neck and shoulder. *(Figure D)*	○	○	○	○

4

A. Description of Work (continued)

Hand / Wrist / Arm

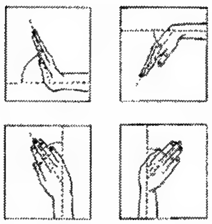


Figure E

Figure F

	NEVER	0-2 HOURS	2-4 HOURS	4-8 HOURS
8. My wrists are bent (up, down, to the thumb or little finger side) while I work. (*Figure E*)	○	○	○	○
9. I apply pressure or hold an item/material/tool (e.g., screwdriver, spray gun, mouse) in my hand for longer than 10 seconds at a time.	○	○	○	○
10. My work requires me to use my hands in a way that is similar to wringing out clothes. (*Figure F*)	○	○	○	○
11. I perform a series of repetitive tasks or movements during the normal course of my work (e.g., using a keyboard, tightening fasteners, cutting meat, etc.)	○	○	○	○
12. The work surface (e.g., desk, bench, etc.) or tool(s) that I use presses into my palm(s), wrists(s) or against the sides of my fingers leaving red marks on or beneath the skin.	○	○	○	○
13. I use my hand/palm like a hammer to do certain aspects of my work	○	○	○	○
14. My hands and fingers are cold when I work	○	○	○	○
15. I work at a fast pace to keep up with a machine production quota or performance incentive	○	○	○	○
16. The tool(s) that I use vibrates and/or jerks my hand(s) and arm(s)	○	○	○	○
17. My work requires that I repeatedly throw or toss items	○	○	○	○
18. My work requires that I twist my forearms, such as when turning a screwdriver	○	○	○	○
19. I wear gloves that are bulky or that reduce my ability to grip	○	○	○	○
20. I squeeze or pinch work objects with a force similar to that which is required to open a lid on a new jar	○	○	○	○
21. I grip work objects or tools as if I am gripping tightly				

A. Description of Work (continued)

Back / Torso

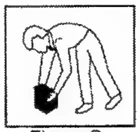


Figure G

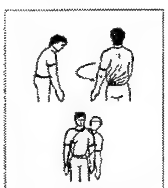


Figure H

Figure I

	NEVER	0-2 HOURS	2-4 HOURS	4-8 HOURS
22. When I lift, move components, or do other aspects of my work, my hands are lower than my knees. *(Figure G)*	○	○	○	○
23. I lean forward continually when I work (e.g., when sitting, when standing, when pushing carts, etc.)	○	○	○	○
24. The personal protective equipment or clothing that I wear limits or restricts my movement.	○	○	○	○
25. I repeatedly bend my back (e.g., forward, backward, to the side, or twist) in the course of my work	○	○	○	○
26. When I lift, my body is twisted and/or I lift quickly. *(Figure H)*	○	○	○	○
27. I can feel vibration through the surface that I stand on or through my seat (e.g., when operating a forklift, truck, etc.)	○	○	○	○
28. I lift and/or carry items with one hand. *(Figure I)*	○	○	○	○
29. I lift or handle bulky items	○	○	○	○
30. I lift materials that weigh more than 25 pounds	○	○	○	○

A. Description of Work (continued)

Legs / Feet

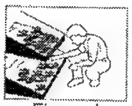


Figure J


Figure K

	NEVER	0-2 HOURS	2-4 HOURS	4-8 HOURS
31. My work requires that I kneel or squat. *(Figure J)*	○	○	○	○
32. I must constantly move or apply pressure with one or both feet (e.g. using foot pedals, driving, etc.)	○	○	○	○
33. When I'm sitting, I cannot rest both feet flat on the floor. *(Figure K)*	○	○	○	○
34. I stand on hard surfaces	○	○	○	○

Head / Eyes

	NEVER	0-2 HOURS	2-4 HOURS	4-8 HOURS
35. I can see glare on my computer screen or work surface	○	○	○	○
36. It is difficult to hear a person on the phone or to concentrate because of other activity, voices, or noise in/near my work area.	○	○	○	○
37. I must look at the monitor screen constantly so that I do not miss important information (radar scope)	○	○	○	○
38. It is difficult to see what I am working with (monitor, paper, parts, etc.)	○	○	○	○

7

B. Organizational Factors

This section asks you to describe organizational factors present in your current work environment.

	STRONGLY DISAGREE	DISAGREE	NEUTRAL	AGREE	STRONGLY AGREE
39. I often feel unclear as to what the scope and responsibilities of my job are.	○	○	○	○	○
40. I often feel that I have too heavy of a workload, one that I could not possibly finish during an ordinary workday	○	○	○	○	○
41. I often feel that I will not be able to satisfy the conflicting demands of various people around me.	○	○	○	○	○
42. I often find myself unable to get information needed to carry out my job.	○	○	○	○	○
43. I often do not know what my supervisor thinks of me ,or how he/she evaluates my performance.	○	○	○	○	○
44. I often think that the amount of work I have to do interferes with how well it is done.	○	○	○	○	○

C. Physical Effort

45. How would you describe the physical effort required of your job?.

1 No exertion at all	2 Extremely light	3	4 Very light	5	6 Light	7	8 Somewhat hard	9	10 Hard	11	12 Very hard	13	14 Extremely hard	15 Maximal exertion
○	○	○	○	○	○	○	○	○	○	○	○	○	○	○

D. Discomfort Factors

This section enables you to identify how your body responds to the demands of your job.

For Shoulder/Neck

46. In the past 12 months have you experienced any discomfort, fatigue, numbness, or pain that *relates to your job*?

○ No ○ Yes

How often do you experience discomfort, fatigue, numbness, or pain in your shoulder/neck region? Mark only one.
○ Daily
○ Weekly
○ Monthly

On average, how severe is the discomfort, fatigue, numbness, or pain in your shoulder/neck region? Mark only one.
○ Mild
○ Moderate
○ Severe

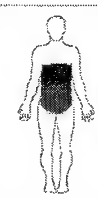
For Hand/Wrist/Arm

47. In the past 12 months have you experienced any discomfort, fatigue, numbness, or pain that *relates to your job*?

○ No ○ Yes

How often do you experience discomfort, fatigue, numbness, or pain in your hands/wrist/arm region? Mark only one.
○ Daily
○ Weekly
○ Monthly

On average, how severe is the discomfort, fatigue, numbness, or pain in your hands/wrist/arm region? Mark only one.
○ Mild
○ Moderate
○ Severe



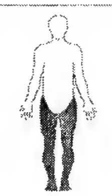
For Back/Torso

48. In the past 12 months have you experienced any discomfort, fatigue, numbness, or pain that *relates to your job*?

○ No ○ Yes

How often do you experience discomfort, fatigue, numbness, or pain in your back/torso region? Mark only one.
○ Daily
○ Weekly
○ Monthly

On average, how severe is the discomfort, fatigue, numbness, or pain in your back/torso region? Mark only one.
○ Mild
○ Moderate
○ Severe



For Legs/Feet

49. In the past 12 months have you experienced any discomfort, fatigue, numbness, or pain that *relates to your job*?

○ No ○ Yes

How often do you experience discomfort, fatigue, numbness, or pain in your legs/feet region? Mark only one.
○ Daily
○ Weekly
○ Monthly

On average, how severe is the discomfort, fatigue, numbness, or pain in your legs/feet region? Mark only one.
○ Mild
○ Moderate
○ Severe

For Head/Eyes

50. In the past 12 months have you experienced any discomfort, fatigue, numbness, or pain that *relates to your job*?

○ No ○ Yes

How often do you experience discomfort, fatigue, numbness, or pain in your head/eyes region? Mark ony one.
○ Daily
○ Weekly
○ Monthly

On average, how severe is the discomfort, fatigue, numbness, or pain in your head/eyes region? Mark only one.
○ Mild
○ Moderate
○ Severe

E. General Questions

51. In the past 12 months have you seen a health care provider for any pain or discomfort that you think *relates to your job*?

○ Yes
○ No

52. Do you experience any work-related pain or discomfort that does not improve when you are away from work overnight or over the weekend?

○ Yes
○ No

53. In the past 12 months, has any work-related pain or discomfort caused you difficulty in carrying out normal activities (e.g., job, hobby, leisure, etc.)?

○ Yes
○ No

54. Has a health care provider ever told you that you have any of the following conditions which you think might be *related to your work*?

○ Yes
○ No

Tendonitis / Tenosynovitis	Ganglion Cyst	Trigger Finger
Epicondylitis (Tennis Elbow)	Bursitis	Carpal Tunnel Syndrome
Thoracic Outlet Syndrome	Back Strain	Knee or Ankle Strain
Overuse Syndrome		

55. Do you have or have you ever had one or more of the following conditions?

○ Yes
○ No

Wrist Fracture	Hypertension	Kidney Disorders
Thyroid Disorder	Diabetes	Gout
Rheumatoid Arthritis		

F. Work Content

The section below enables you to describe the content of the work that you do <u>in your current job.</u>
Fill in the box that describes how frequently you do the task listed, based on the following definitions:

Routine: Performed on three or more days per week.
Non-routine: Performed two days a week or less.
Seasonal: Performed only during certain times of the year.
Never: You do not perform this type of work.

Task	ROUTINE	NON-ROUTINE	SEASONAL	NEVER
56. Abrading	○	○	○	○
57. Baking	○	○	○	○
58. Bolting/screwing	○	○	○	○
59. Calling (telephone use)	○	○	○	○
60. Chipping	○	○	○	○
61. Cleaning by hand	○	○	○	○
62. Cleaning with high pressure equipment	○	○	○	○
63. Coating/immersing	○	○	○	○
64. Cooking	○	○	○	○
65. Copying	○	○	○	○
66. Crimping	○	○	○	○
67. Cutting/shearing	○	○	○	○
68. Drafting/CAD system use	○	○	○	○
69. Drilling	○	○	○	○
70. Driving (vehicles)	○	○	○	○
71 Excavating	○	○	○	○
72. Filing/general administrative	○	○	○	○
73. Flame cutting/arc cutting	○	○	○	○
74. Folding/fitting	○	○	○	○
75. Gluing/laminating	○	○	○	○
76. Grinding/buffing/polishing	○	○	○	○
77. Hammering	○	○	○	○
78. Lifting	○	○	○	○
79. Loading (pallets, trucks, carts, aircraft)	○	○	○	○
80. Lubricating	○	○	○	○
81. Machining	○	○	○	○
82. Masoning	○	○	○	○
83. Melting	○	○	○	○
84. Molding	○	○	○	○
85. Monitoring (visual displays)	○	○	○	○
86. Mousing (for computer work)	○	○	○	○
87. Nailing	○	○	○	○
88. Opening/closing heavy doors	○	○	○	○
89. Packing/packaging	○	○	○	○
90. Painting/spray painting	○	○	○	○
91. Paving	○	○	○	○
92. Pumping (by hand)	○	○	○	○
93. Riveting/bucking	○	○	○	○
94. Sanding	○	○	○	○
95. Sawing	○	○	○	○
96. Scanning (using bar code readers)	○	○	○	○
97. Sewing	○	○	○	○
98. Soldering/brazing	○	○	○	○
99. Stapling	○	○	○	○
100. Stripping/depainting by hand	○	○	○	○
101. Stripping/depainting mechanically	○	○	○	○
102. Transporting loads on non-powered carts	○	○	○	○
103. Turning valves	○	○	○	○
104. Tying/twisting/wrapping	○	○	○	○
105. Typing/keying	○	○	○	○
106. Welding	○	○	○	○
107. Wheeling loads	○	○	○	○
108. Wiring	○	○	○	○
109. Wrenching/ratcheting	○	○	○	○
110. Writing/illustrating	○	○	○	○
Please write in others here:				
111.________________	○	○	○	○
112.________________	○	○	○	○

11

Page 12 of the JRPD form could not be scanned. Page 12 text is as follows:

G. Process Improvement Opportunities

Think about your job as a whole, including routine, non-routine, or seasonal work.

Read the questions listed below and describe the activities that you or your co-workers think place the greatest demands on your body.

113. Which tasks are the most awkward or require you to work in the most uncomfortable position?

114. Which tasks take the most effort?

115. Are there any tools or pieces of equipment that are notoriously hard to work with?

(If possible, provide manufacturer and model.)

116. If you could make any suggestions that would help you do your job easier, faster, or better, what would you suggest?

Appendix G: JRPD Summaries and Interpretations

USAF Job Requirements and Physical Demands Survey (All Sites)

	Body Parts				
	Shoulder/Neck	Hand/Wrist/Arm	Back/Torso	Leg/Torso	Head/Eye
Priority Score	3	1	1	3	7
Risk Prevalence	19%	4%	7%	30%	63%
Risk Rating	Low	Low	Low	Low	High
Discomfort Prevalence	33%	19%	19%	41%	37%
Discomfort Rating	Medium	Low	Low	Medium	Medium

Overall Priority	7
EPRA	Yes

Surveys Analyzed	27
Eligible Workers	27
Response Rate	100%
Survey Date	10/30/1998

Other Information

Organizational Score	**Low**	
Job stress factors are of minimal concern.		
Avg Physical Effort Score	**5.07**	12
Health Care Provider Score	**7**	2
Use this number to identify potential under-reporting.		
Recovery Time Score	**40.74**	2
Likely EPRA. If not, compare with discomfort ratings and consider an ergonomic evaluation.		
Activity Interruption Score	**25.93**	2
Previous Diagnosis Score	**18.52**	2
Contributing Factors Score	**51.85**	2
Contributing factors may have inflated overall priority.		

Demographics

Gender:	4% Female	93% Male	
Group:	19% Civilians	0% Contractors	0% Foreign Nationals
	7% National Guard	0% Active Duty	0% Military Reserve

Years at base:	Years at job:	Age:	
0% < 1 yr	0% < 1 yr	0% <20 yrs	19% 46-50 yrs
4% 1-5 yrs	4% 1-5 yrs	4% 21-25 yrs	26% 51-55 yrs
4% 6-10 yrs	4% 6-10 yrs	7% 26-30 yrs	7% 56-60 yrs
4% 11-15 yrs	4% 11-15 yrs	0% 31-35 yrs	4% 61-65 yrs
4% 16-20 yrs	4% 16-20 yrs	4% 36-40 yrs	4% >65 yrs
0% > 20 yrs	0% > 20 yrs	19% 41-45 yrs	

Note: Totals may not add up to 100% due to missing data

USAF Job Requirements and Physical Demands Survey (Bonneville Lock)

	Body Parts				
	Shoulder/Neck	Hand/Wrist/Arm	Back/Torso	Leg/Feet	Head/Eye
Priority Score	1	1	1	1	1
Risk Prevalence	0%	0%	0%	11%	22%
Risk Rating	Low	Low	Low	Low	Low
Discomfort Prevalence	22%	0%	0%	0%	0%
Discomfort Rating	Low	Low	Low	Low	Low

Overall Priority	1
EPRA	No

Surveys Analyzed	9
Eligible Workers	9
Response Rate	100%
Survey Date	10/30/1998

Other Information

Organizational Score	**Low**	
Job stress factors are of minimal concern.		
Avg Physical Effort Score	**4.78**	6
Health Care Provider Score	**2**	1
Use this number to identify potential under-reporting.		
Recovery Time Score	**22.22**	1
Activity Interruption Score	**22.22**	1
Previous Diagnosis Score	**0.00**	1
Contributing Factors Score	**33.33**	1
Contributing factors may have inflated overall priority.		

Demographics

Gender:	11% Female	89% Male	
Group:	44% Civilians	0% Contractors	0% Foreign Nationals
	11% National Guard	0% Active Duty	0% Military Reserve

Years at base:	Years at job:	Age:	
0% < 1 yr	0% < 1 yr	0% <20 yrs	22% 46-50 yrs
11% 1-5 yrs	11% 1-5 yrs	0% 21-25 yrs	33% 51-55 yrs
11% 6-10 yrs	11% 6-10 yrs	11% 26-30 yrs	0% 56-60 yrs
11% 11-15 yrs	11% 11-15 yrs	0% 31-35 yrs	11% 61-65 yrs
11% 16-20 yrs	11% 16-20 yrs	11% 36-40 yrs	0% >65 yrs
0% > 20 yrs	0% > 20 yrs	11% 41-45 yrs	

Note: Totals may not add up to 100% due to missing data

USAF Job Requirements and Physical Demands Survey (Melvin Price Locks)

	Body Parts				
	Shoulder/Neck	**Hand/Wrist/Arm**	**Back/Torso**	**Leg/Torso**	**Head/Eye**
Priority Score	3	1	1	3	7
Risk Prevalence	19%	4%	7%	30%	63%
Risk Rating	Low	Low	Low	Low	High
Discomfort Prevalence	33%	19%	19%	41%	37%
Discomfort Rating	Medium	Low	Low	Medium	Medium

Overall Priority	7
EPRA	Yes

Surveys Analyzed	27
Eligible Workers	27
Response Rate	100%
Survey Date	10/30/1998

Other Information

Organizational Score	**Low**	
Job stress factors are of minimal concern.		
Avg Physical Effort Score	**5.07**	12
Health Care Provider Score	**7**	2
Use this number to identify potential under-reporting.		
Recovery Time Score	**40.74**	2
Likely EPRA. If not, compare with discomfort ratings and consider an ergonomic evaluation.		
Activity Interruption Score	**25.93**	2
Previous Diagnosis Score	**18.52**	2
Contributing Factors Score	**51.85**	2
Contributing factors may have inflated overall priority.		

Demographics

Gender:	4% Female	93% Male	
Group:	19% Civilians	0% Contractors	0% Foreign Nationals
	7% National Guard	0% Active Duty	0% Military Reserve

Years at base:	Years at job:	Age:	
0% < 1 yr	0% < 1 yr	0% <20 yrs	19% 46-50 yrs
4% 1-5 yrs	4% 1-5 yrs	4% 21-25 yrs	26% 51-55 yrs
4% 6-10 yrs	4% 6-10 yrs	7% 26-30 yrs	7% 56-60 yrs
4% 11-15 yrs	4% 11-15 yrs	0% 31-35 yrs	4% 61-65 yrs
4% 16-20 yrs	4% 16-20 yrs	4% 36-40 yrs	4% >65 yrs
0% > 20 yrs	0% > 20 yrs	19% 41-45 yrs	

Note: Totals may not add up to 100% due to missing data

USAF Job Requirements and Physical Demands Survey (Kentucky)

	Body Parts				
	Shoulder/Neck	Hand/Wrist/Arm	Back/Torso	Leg/Torso	Head/Eye
Priority Score	2	1	1	9	7
Risk Prevalence	36%	0%	18%	64%	82%
Risk Rating	Medium	Low	Low	High	High
Discomfort Prevalence	27%	18%	27%	73%	45%
Discomfort Rating	Low	Low	Low	High	Medium

Overall Priority	9
EPRA	Yes

Surveys Analyzed	11
Eligible Workers	11
Response Rate	100%
Survey Date	

Other Information

Organizational Score	**Low**	
Job stress factors are of minimal concern.		
Avg Physical Effort Score	**5.55**	3
Health Care Provider Score	**3**	0
Use this number to identify potential under-reporting.		
Recovery Time Score	**54.55**	0
Likely EPRA. If not, compare with discomfort ratings and consider an ergonomic evaluation.		
Activity Interruption Score	**27.27**	0
Previous Diagnosis Score	**9.09**	0
Contributing Factors Score	**45.45**	0
Contributing factors may have inflated overall priority.		

Demographics

Gender: 0% Female, 100% Male

Group: 0% Civilians, 0% Contractors, 0% Foreign Nationals, 9% National Guard, 0% Active Duty, 0% Military Reserve

Years at base:	Years at job:	Age:	
0% < 1 yr	0% < 1 yr	0% <20 yrs	9% 46-50 yrs
0% 1-5 yrs	0% 1-5 yrs	9% 21-25 yrs	18% 51-55 yrs
0% 6-10 yrs	0% 6-10 yrs	9% 26-30 yrs	9% 56-60 yrs
0% 11-15 yrs	0% 11-15 yrs	0% 31-35 yrs	0% 61-65 yrs
0% 16-20 yrs	0% 16-20 yrs	0% 36-40 yrs	9% >65 yrs
0% > 20 yrs	0% > 20 yrs	27% 41-45 yrs	

Note: Totals may not add up to 100% due to missing data

Interpretation of Results

Survey Priority Rank

The Survey Priority Rank provides you with a numeric indication of the prevalence of ergonomic risk factors and workplace musculoskeletal disorders (WMSD) within a shop. The Survey Priority Rank does not indicate the severity of the risk. Additional analyses are required to make that determination.

If the Survey Priority Rank score is 5 or above, it indicates the presence of both ergonomic risk factors and discomfort for a majority of the people within a shop.

Intervention priority is determined by the Survey Priority Rank score. A higher score indicates a higher intervention priority.

If the Survey Priority Rank score is less than 5, it indicates that the majority of the people in the shop do not have work-related discomfort combined with recognized risk factors. A review of the comments and the shop injury history may be useful when searching for hazardous conditions with lower overall prevalence.

The JRPD results indicated that the Barkley Lock Control Room and Melvin Price Locks Control Room both with a Priority Score of 9 are the locations with the highest degree of prevalence for ergonomic risk factors, the body parts most at risk are the legs/feet and the head/eyes. Finally, the Bonneville Lock Control room had a priority score of 1. Furthermore the risk rating and discomfort rating for every body part was low. This rating indicates a low prevalence for ergonomic risk factors at this location.

Questions 1 through 38 in the Description of Work Section (A) and questions 46 through 50 in the Discomfort Factors Section (D) in the JRPD are used to determine the prevalence and severity of ergonomic risk factors and WMSD within a shop, which leads to the Survey Priority Rank.

Organizational Factor Rating

A rating of High in the Organization Factors section indicates that many of the people in the area experience situations at work that can lead to a higher than normal level of job stress. High levels of job stress can decrease job performance, increase the potential for heart disease, and increase the experience of pain and discomfort. A High Organizational Factor Rating suggests consideration for fol-

low-up job stress evaluation. If the Organizational Factor Rating is Medium, the supervisor should consider job stress factors when reviewing an area. A Low Organizational Factor Rating suggests minimal concerns for job-related stress factors in that shop.

All three lock control room locations indicated that organizational factors at their jobs were low. This rating indicates the lock control room operators are clear to what the scope and responsibilities of their job are; they feel their workload is appropriate; they know how their performance is evaluated; and the time given for work is appropriate for it to be completed.

Questions 39 through 44 in the JRPD are used to determine the Organizational Factors Rating.

Physical Effort Factor Score

The numeric score indicates the average level of perceived exertion. The higher the score the greater the level of physiological exertion present within a shop. A Physical Effort Factor of 15 or higher could explain a high discomfort rating for a shop, in spite of a low ergonomic risk factor rating. A score in this range suggests consideration for follow-up evaluation regardless of Survey Priority Rank. The 15 corresponds to "hard" on the physical effort scale. This rating was selected as a threshold since workers who perceive their work to be "hard" may be more likely to report discomfort or to seek a need for follow-up. If the score is below 15, these numbers can be compared between shops to assess the relative physiological stress within each shop. Caution — a score in this range does not indicate low ergonomic risk.

The Barkley Lock Control Room (Kentucky) had the highest Average Physical Effort Score with 5.55. A value of 6 on the physical effort scale indicates that the degree of physical exertion is light. Thus all locations indicate that the level of physical effort required on the job is somewhat less than light.

Question 45 in the JRPD is used to determine the Physical Effort Factor Score.

Health Care Provider Visits

This score indicates the number of people within the shop who indicate that they have sought medical attention during the previous year for work-related discom-

fort. This number can be compared with injury and illness rates for the shop to identify potential under-reporting.

The survey results indicate that 7 of the 27 lock control room operators had sought medical attention. The percentage of people seeking treatment was 22 percent for Bonneville, 27 percent for Melvin Price, and 28 percent for Barkley. This implies that about one out of every four lock control room operators is seeking medical attention for pain they feel is being caused by their jobs.

Question 51 in the JRPD is used to determine the Health Care Provider Visits Score.

Recovery Time Score

This percentage provides a comparison with the Discomfort Rating. If the Recovery Time Score is above 30 percent, this area has likely been classified as an ergonomics problem area (EPRA) by the Survey Priority Rank. If the shop was not classified as EPRA, the scoring of the Discomfort Rating section could be reviewed to verify accuracy. Since this is an alternate measure of discomfort severity, a shop with a percentage in this range should receive further investigation by the ergonomics working group (EWG), regardless of EPRA status. The 30 percent threshold was selected as a conservative starting point for further evaluation. If the percentage is below 30 percent, verification of Discomfort Rating section scoring is not necessary. A shop with a percentage in this range may be either an EPRA or a non-EPRA shop depending on other factors.

The Recovery Time Score is a percentage that indicates if an employee has suffered some type of work-related pain or discomfort that does not improve when they are away from work overnight or over the weekend. Of the 27 lock operators surveyed, 11 indicated that they have suffered some type of pain or discomfort that did not improve overnight or over the weekend. The Barkley Lock had the highest percentage of people (54.55 percent or 6 of 11 lock operators) reporting discomfort that did not go away overnight.

Question 52 in the JRPD is used to determine the Recovery Time Score.

Activity Interruption Score

This percentage provides an additional comparison with the Discomfort Ratings. If the Activity Interruption score is above 50 percent, this area has likely been

classified as an EPRA by the Survey Priority Rank. If the shop was not classified as an EPRA, the scoring of the Discomfort Rating section could be reviewed to verify accuracy. Since this is an alternate measure of discomfort severity, a shop with a percentage in this range should receive further investigation by the EWG, regardless of EPRA status. The 50 percent threshold was selected as a conservative starting point for further evaluation. If the percentage is below 50 percent, verification of the Discomfort Rating is not necessary. A shop with a percentage in this range may be either an EPRA or a non-EPRA shop depending on other factors.

The Activity Interruption Score for all sites ranged from 22 to 29 percent. This indicated that about one in four lock operators has had work-related pain or discomfort that has caused them difficulty in performing normal job, hobby, or leisure activities. These figures are also consistent with the number of people seeking medical attention for pain believed to be work related.

Question 53 in the JRPD is used to determine the Activity Interruption Score.

Previous Diagnosis Score

This percentage provides a mitigating factor to compare with the Discomfort Rating. If the Previous Diagnosis score is above 20 percent, the discomfort ratings could have been impacted by a high degree of people with previous conditions. If a shop has more than 20 percent of the people with previous conditions, the shop could have a false positive EPRA determination based on the Survey Priority Rank. This would most likely occur in cases where body areas had a High rating for discomfort with either Medium or Low ratings for risk factors. If you suspect that a shop may have a false positive EPRA status, you can re-evaluate the shop by removing the discomfort scores for people with previous diagnoses and re-scoring the Discomfort section and Survey Priority Rank. This new score may provide a better indication of the current ergonomic hazard level within the shop. The 20 percent threshold was selected as a conservative starting point for further evaluation. If the percentage is below 20 percent, it can be assumed that the prevalence of previous diagnosis within a shop had a minimal impact on the scoring for that shop.

Only one lock operator at the Bonneville Lock and one at the Barkley Lock had been diagnosed with a cumulative trauma disorder-type injury. However, four of the seven lock operators at the Melvin Price Locks had been diagnosed with cumulative trauma disorder-type injuries. The small sample size makes it difficult

to determine why the employees at the Melvin Price Locks had a higher injury rate. Potential explanations might be that it is a centrally located lock; the volume of traffic going through the Melvin Price Locks may be higher than the other surveyed locks; the average age of the Melvin Price Locks Control Room operators is higher than the other surveyed sites; the Contributing Factors Score (discussed next) was 86 percent, a value that is at least 40 percent greater than both of the other sites; or a combination of these factors.

Question 54 in the JRPD is used to determine the Previous Diagnosis Score.

Contributing Factors Score

This percentage provides another mitigating factor to compare with the Discomfort Rating. If the Contributing Factors score is above 20 percent, the discomfort ratings could have been impacted by a high degree of people with conditions that increase the prevalence of cumulative trauma disorders. A shop that was ranked an EPRA on the basis of high discomfort, with either medium or low risk factor ratings, may represent a false positive ranking. This shop could be re-evaluated by removing the discomfort scores for people with contributing factors and re-scoring the Discomfort section and Survey Priority Rank. This new score may provide a better indication of the current ergonomic hazard level within the shop. The 20 percent threshold was selected as a conservative starting point for further evaluation. If the percentage is below 20 percent, it can be assumed that the prevalence of contributing factors within a shop had a minimal impact on the scoring for that shop.

All sites had a high Contributing Factors score; 33, 45, and 86 percent for Bonneville, Barkley, and Melvin Price locks, respectively. These values indicate that the employees at the locks have personal risk factors that are associated with cumulative trauma disorders and thus it may be the employees current health status and not the working conditions that are the cause for discomfort and medical attention.

Question 55 in the JRPD is used to determine the Contributing Factors Score.

Overall Results

The JRPD results displayed a few trends. The lock control room operators were predominately male with the median age being over 46 years old. The operators

were clear as to their job duties; they knew the criteria on which their supervisors judged them; and, for the most part, they felt their workloads were appropriate. They also indicated the physical demands of the job were light.

The head/eye body region was the area at greatest risk for an injury and the most uncomfortable. This risk factor is understandable since the great majority of the tasks performed require working at control panels and looking at video monitors. The workstations were not adjustable, thereby forcing the operators to adjust their posture.

Just over one in four operators visited a health care provider in the previous year for pain they believed to be work related. Also, 41 percent of the operators indicated that they had discomfort or pain that did not improve either overnight or over the course of the weekend. Additionally, 26 percent of the operators had work-related discomfort or pain that caused them difficulty in performing work, leisure, or hobby activities. Almost 20 percent of all lock operators had been diagnosed with some type of cumulative trauma disorder, and over half of the lock operators had been diagnosed with some type of personal risk factor for a cumulative trauma disorder-type injury.

Also, the survey results indicated that the lock operators at the Melvin Price Locks were skewing the injury figures toward the high end. This means that work in a central control room, which is more sedentary than work in a local control room, may be the cause of many of the reported problems.

Unfortunately, it is difficult to say what is causing the high number of health care provider visits and long discomfort and pain recovery times. It seems that age, sedentary work, and lack of adjustable workstations may all play a part in the comfort and health of the lock operators.

Appendix H: Lock Operator Suggestions

Melvin Price Locks

Comment	*No. of Responses*
Provide voice mail or an answering machine	6
Improve the quality of the shades	2
Improve the tinting on the windows	1
Tilt the windows to better deflect glare	2
Provide search lights	1

Barkley Lock

Comment	*No. of Responses*
Provide one centralized control stand	3
Provide bigger control stands	1
Provide ergonomically controlled (*designed*) stands/controls	1
Provide means for viewing barges from the control stand	1
Fix halage unit remote	1
Provide laptop computer at the operator desk	1
Provide lock operators with their own desks	1

Eliminate phone calls while operators are locking a vessel	1
Provide additional cameras/monitors for security purposes	1
Install a security fence (for people who work at night)	1
Provide a covered cart (rain/snow)	1

Bonneville Lock

Comment	*No. of Responses*
Provide a covered cart (rain/snow)	1
Provide a working bypass system	1

Appendix I: Melvin Price Locks Control Room Redesign

Following are the problems identified at the Melvin Price Locks Control Room:

- The room was too hot in the summer and too cold in the winter.
- There was glare in the control room when the sun was shining.
- The floor surface was too hard.
- Control of indoor light levels was difficult.
- Workstations were designed for seated work only.
- Panel controls were too far away from the operators.
- Workstations for computer tasks were not fully adjustable.
- Operators spent a lot of time communicating via phone or radio.

To eliminate or minimize the problems faced by the operators in the Melvin Price Locks Control Room, the following actions should be taken:

- Purchase heating and cooling units based on the potential indoor temperatures that need to be regulated and not based on the square footage of the area to be heated or cooled.
- To combat the effects of glare in the control room, install all windows with a tilt of 20 degrees and investigate the use of electronically controlled polarized lights and easy-to-operate shades and blinds for all windows. Also, if feasible and approved by the lock operators, block between one quarter and one half of windows with a material that does not allow light to pass through. This will aid in temperature regulation and will help to reduce glare in the control room.
- Cover flooring with antifatigue matting. The Occupational Safety and Health Administration recommends that antifatigue matting be at least ½-in. thick. This addition may also aid in regulating the indoor climate.
- Ensure all lighting inside the control room is incandescent and operated by a dimmer switch. Also, all windows should have easy-to-operate shades and blinds. These items will help operators regulate how much light they want in the control room.

- Supply task lighting with multiple settings or a dimmer switch at every desk, which will allow the operators to place more light where it is needed.
- Ensure all walls and furniture are dark in color and have a matte finish. This flat color will reduce the amount of glare reflecting off surfaces in the control room.
- Ensure all functions that can be performed remotely are integrated into the computer systems that are handy for the lock operators. Then the locks, window shades, baffles, marine radio, etc., can be operated with one computer (as at the Beatrix Lock). This will eliminate clutter and allow the lock operator to perform more tasks even if he or she cannot leave the computer workstation.
- Improve the adjustability of CCTV workstations by providing chairs and desks that have multiple adjustability features.

  – Provide a desk that can be adjusted in height from 23.6 in. to 47.0 in. (This range will allow 95 percent of the work force to type at the workstation while either sitting or standing.)

  – Provide a chair that can be adjusted in height from 16 to 21 in. See Appendix J, Chair Fact Sheet, for other recommended features.

  – Provide a control console with controls no further than 20 in. away from the operator. This will allow the people with the shortest arm lengths to operate all console controls without having to lean forward in the chair.

  – Ensure ceiling mounted CCTV monitors are no more than 3 ft above the lock operator's workstation. If feasible, the ceiling-mounted CCTV monitors should be on a bracket that is height adjustable. If multiple monitors are to be used, the monitors should be aligned in an arc to aid the operator in viewing.

  – Ensure CCTV monitors have screen diagonals that measure at least 25 in.

- Provide a computer workstation dedicated to operation of the OMNI program. This workstation should contain a bi-level desk with a keyboard portion that can be adjusted in height from 23.6 in. to 47.0 in. A monitor portion that can be adjusted in height from 28 in. to 52 in. The workstation should also contain a chair that can be adjusted in height from 16 to 21 in. and hands-free communication devices. Consider a cordless headset for telephone

use and a foot operated radio. This will allow the lock operator to communicate while keeping both hands free to enter data on paper or into the computer.

- Lastly, ensure the lock control room is a place where the operator wants to work. Make every effort to make the control room large, comfortable, and aesthetically pleasing. This will help eliminate some of the stress to which the operators are exposed.

Figures I1 through I5 are drawings of the redesigned Melvin Price Locks Control Room.

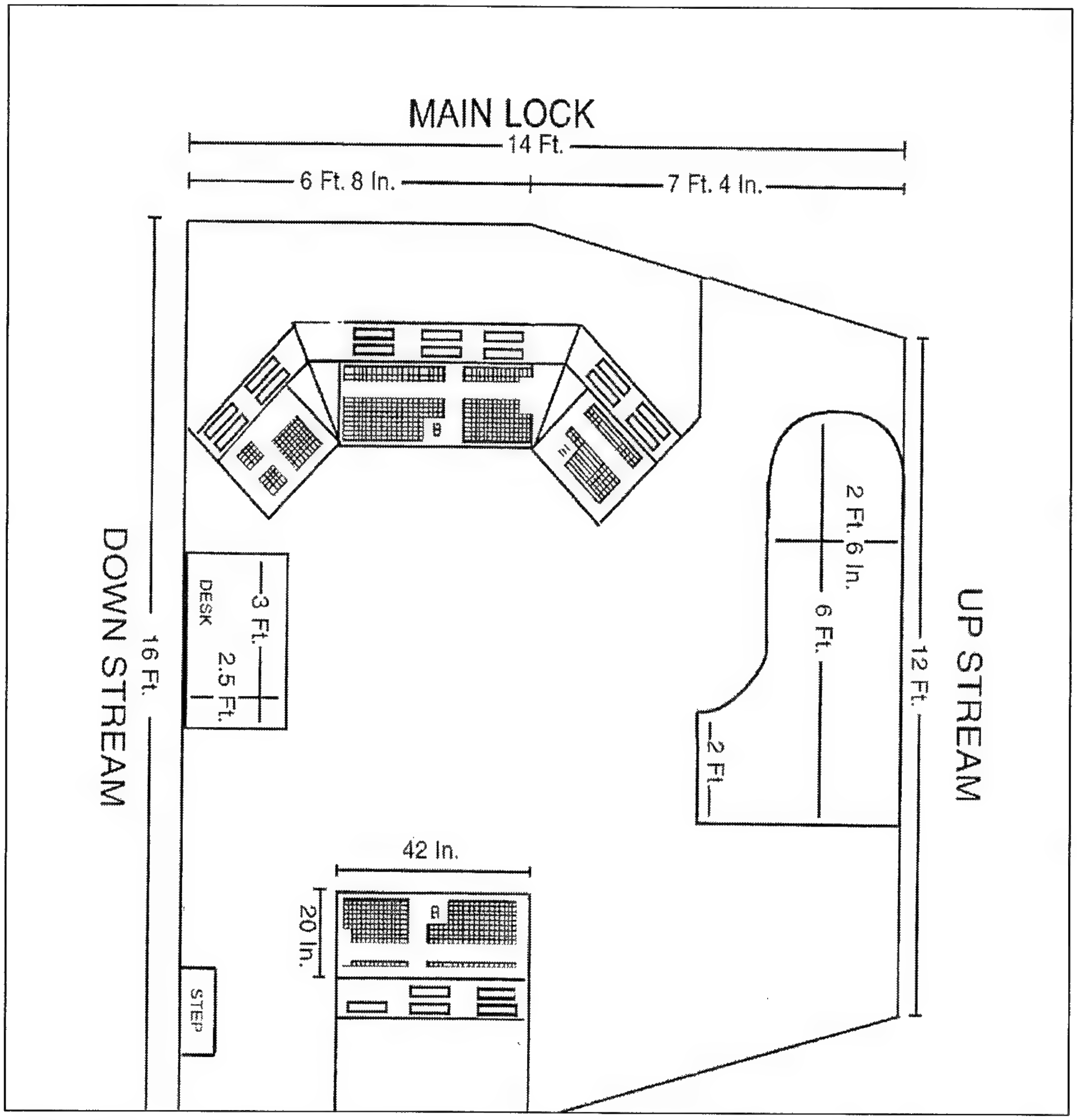


Figure I1. Top view of redesigned Melvin Price Locks Control Room.

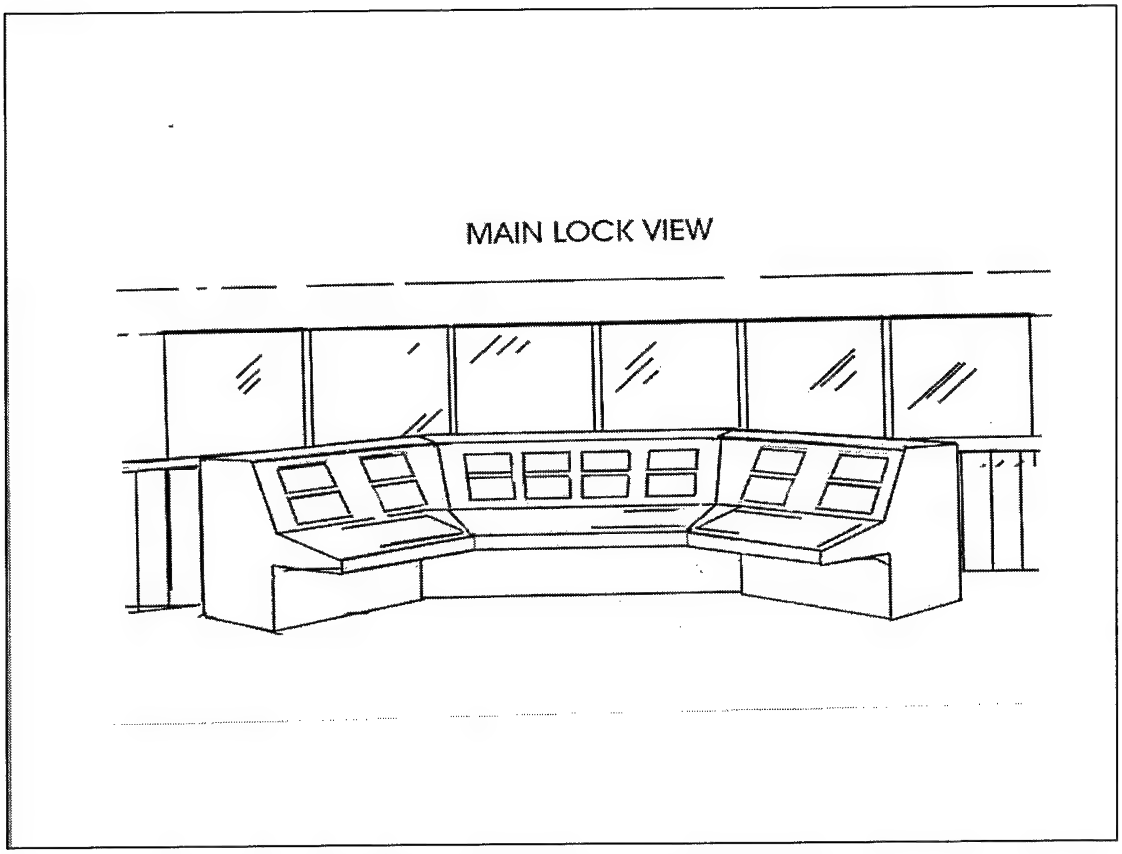


Figure I2. Main lock view of redesigned Melvin Price Locks Control Room.

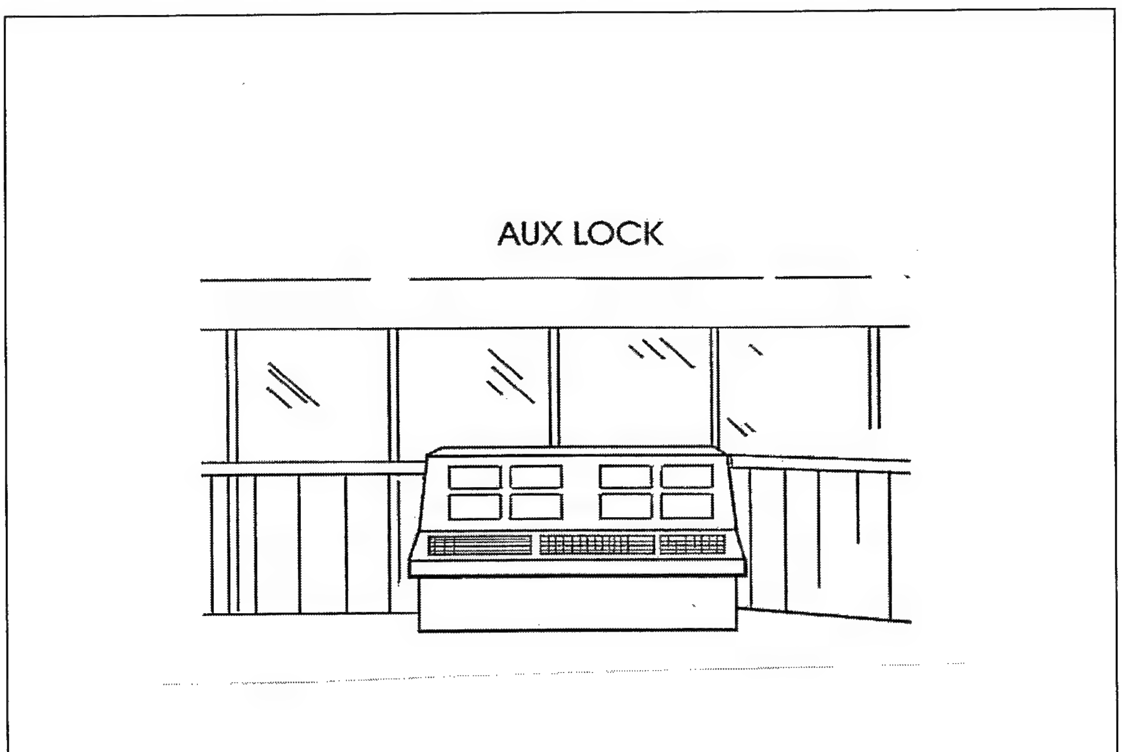


Figure I3. Auxiliary view of redesigned Melvin Price Locks Control Room.

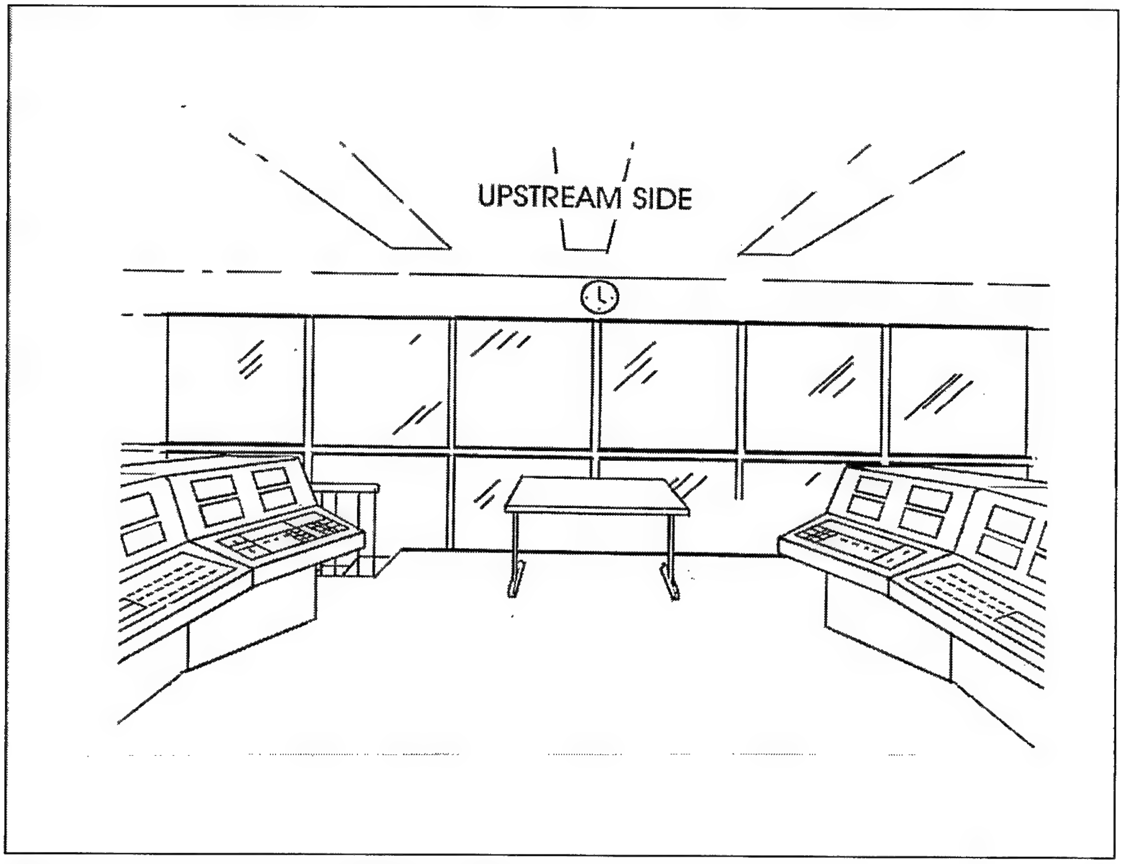


Figure I4. Upstream view of redesigned Melvin Price Locks Control Room.

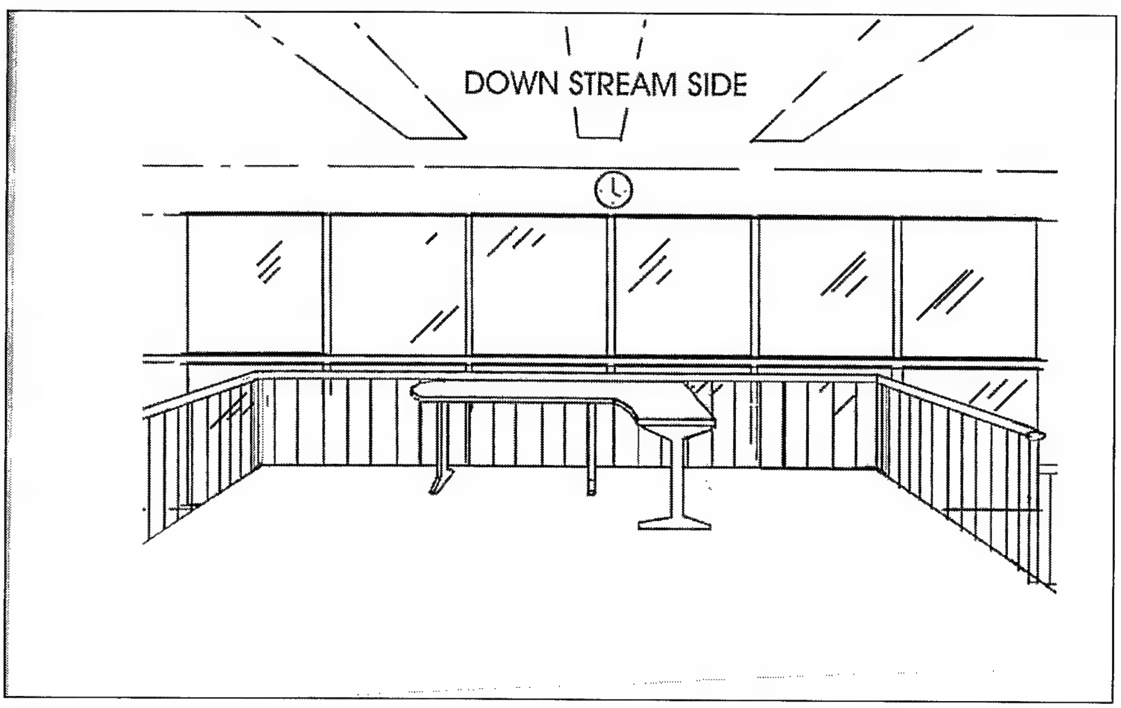


Figure I5. Downstream view of redesigned Melvin Price Locks Control Room.

Appendix J: Chair Fact Sheet

USACHPPM
Readiness thru Health

88-004-0599

Just the Facts...

Ergonomic Chair Features

◆ *Safety and Health Professionals*

◆ *Adaptability*

◆ *Individual Characteristics*

People vary widely in their shapes and sizes, and the chairs they use should reflect this characteristic. Workers should be able to select from a variety of different chair models.

A "poorly fitting" chair may introduce musculoskeletal problems or aggravate existing conditions. Compressive forces on the spine are greater when sitting than when standing. Fatigue and discomfort result when muscles and joints are forced into awkward postures, especially after prolonged sitting.

The chair is the most intimate piece of equipment the office worker has, yet it is often overlooked in the design of a workstation. Whether in a conference room, at a computer workstation, or at a drafting stand, the chair must be designed with function in mind. For example, a cozy, stylish conference chair may present problems for the office worker who types for a long period of time each day.

Currently there are no restrictions on using the term "ergonomically designed" to describe chairs or any other type of office furniture. Pay attention to the claims made by chair manufacturers.

Fitting the Population

The chair must adjust to the size and comfort of each worker. Not only should the chair raise and lower to accommodate varying heights, but the seat depth should adjust as well. If the seat depth of the chair is too great, the back support cannot be used.

An adjustable seat angle is beneficial for the office worker. A forward sloping seat, or "waterfall front," is helpful to relieve pressure on the backs of the legs while the worker is typing or writing. A 5-degree backward slope promotes use of the backrest and prevents the worker from sliding forward. The backrest should support the lumbar spine but not restrict its movement.

The armrest should be adjustable for height, width between armrests, and distance to the seat front. These adjustments are important for reducing the pressure on the seat surface and the load on the spine. The length and width of the armrests must also be considered. Armrests can become obstacles when they are too wide or too high (e.g., armrests that prevent a chair from sliding under a table). When awkwardly positioned, armrests may hinder a worker getting out of the chair. Five casters are necessary to prevent the chair from tipping. The casters must roll over carpeted surfaces easily.

The chair evaluation checklist, on the back, should guide you in selecting a chair that can be adapted to your individual needs.

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Chair Evaluation Checklist

Yes	No	
☐	☐	If the seat is a fixed height, is the seat pan 18 to 19 inches high?
☐	☐	If the seat is adjustable, is the seat pan 16 to 20.5 inches high?
☐	☐	Does the seat pan adjust from an angle of 5 to 15 degrees forward tilt to 5 degrees backward tilt and lock in place?
☐	☐	Is the seat 15 to 17 inches deep (i.e., does the seat back move in over the seat pan)?
☐	☐	Is the seat pan at least 18.2 inches wide?
☐	☐	Does the seat have a rounded, waterfall front seat edge?
☐	☐	Does the amount of contouring support postures, distribute pressures, and provide freedom of movement?
☐	☐	Does the seat cushion thickness range from 1.5 to 2.0 inches?
☐	☐	Does the seat covering "give" and "breathe"?
☐	☐	Is the seat back angle a minimum of 90 to 105 degrees (preferably up to 120 degrees), and does it lock in position?
☐	☐	Is the seat back width in the lumbar region at least 12 inches?
☐	☐	Is the seat back 15 to 20 inches high?
☐	☐	Is the height of the lumbar support adjustable?
☐	☐	Does the lumbar support move upward relative to the lumber spine as the backrest reclines?
☐	☐	Is the lumbar support 6 to 9 inches long and 12 inches wide?
☐	☐	Is the lumbar support positioned 6 to 10 inches above the seat?
☐	☐	Does the lumbar support protrude forward about 2 inches from the back of the seat?
☐	☐	Does the chair have a stable five-point base with casters?
☐	☐	Does the chair have adjustable armrests?
☐	☐	Are the armrests 9 to 12 inches long and 8 to 9 inches above the seat?
☐	☐	Is the chair easily adjustable?
☐	☐	Can the controls be easily reached and adjusted from the standard seated work position?
☐	☐	Do the controls provide immediate feedback?
☐	☐	Is the direction of operation of controls logical and consistent?
☐	☐	Do adjustments require the use of only one hand?
☐	☐	Does the chair pivot 360 degrees, allowing easy ingress/egress and access to various surfaces?

*** Any question answered NO indicates a potential problem area.**

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14. ABSTRACT

Between 23 September and 30 October 1998, an ergonomics team from the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) evaluated the lock control rooms and consoles at the Melvin Price Locks and Dam (Illinois), the Bonneville Lock and Dam (Oregon), the Kentucky Lock and Dam (Kentucky), and the Barkley Lock and Dam (Kentucky). From 10 to 19 November 1999, the USACHPPM team evaluated eight European lock control rooms and consoles. The evaluation team identified deficiencies in the design of the control room and in the design of the console. Lock control operators encountered other stressful conditions as well.

15. SUBJECT TERMS
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